

## Hurricane and Severe Storm Sentinel (HS3) Mission

### HS3 2014-08-26 Flight Report: GLOBALHAWK AV-6 Transit and first Cristobal Flight

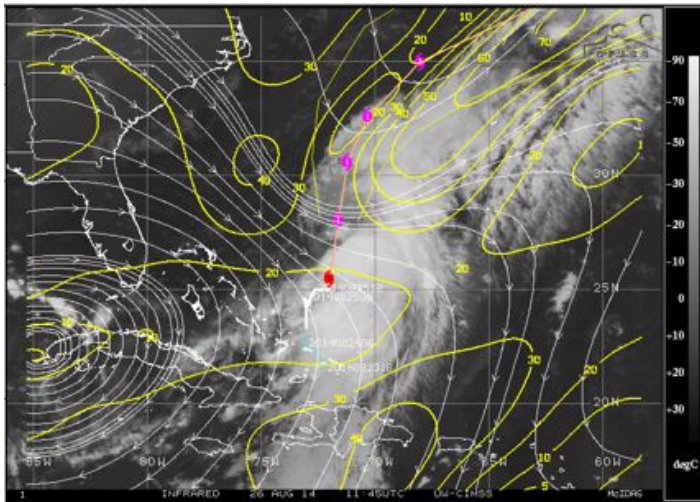
Flight Scientists:

Shift 1 (0400-1300 EDT): Scott Braun, Pete Black

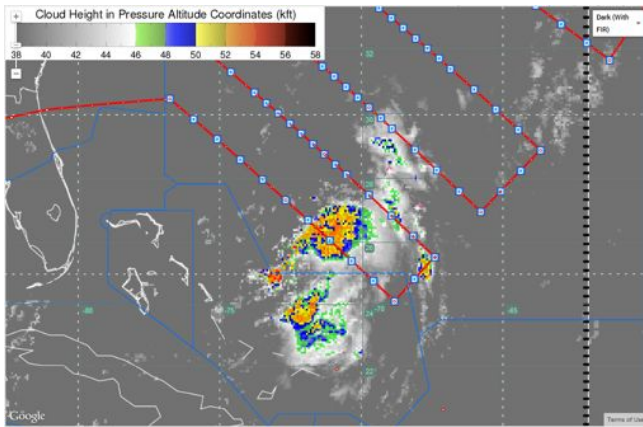
Shift 2 (1200-2100 EDT): Paul Newman, Jason Sippel, Bob Houze

Shift 3 (2000-0500 EDT): Dan Cecil, Steve Guimond, Jason Dunion

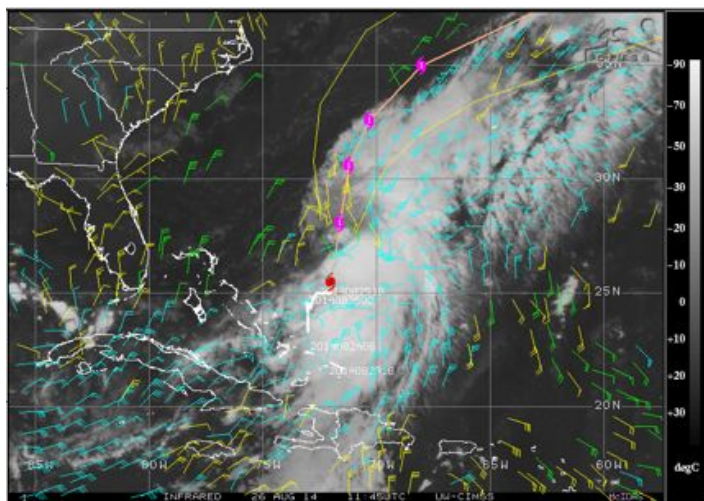
Mission goal: Transit of AV-6 from AFRC to WFF and first science flight into Hurricane Cristobal. Cristobal is currently under moderate to strong shear causing the system to be highly asymmetric. SHIPS forecast calls for weakening shear in the next 12-24 h which could allow for improved organization and additional intensification.



GOES image at 1145 UTC showing IR and deep layer vertical wind shear.

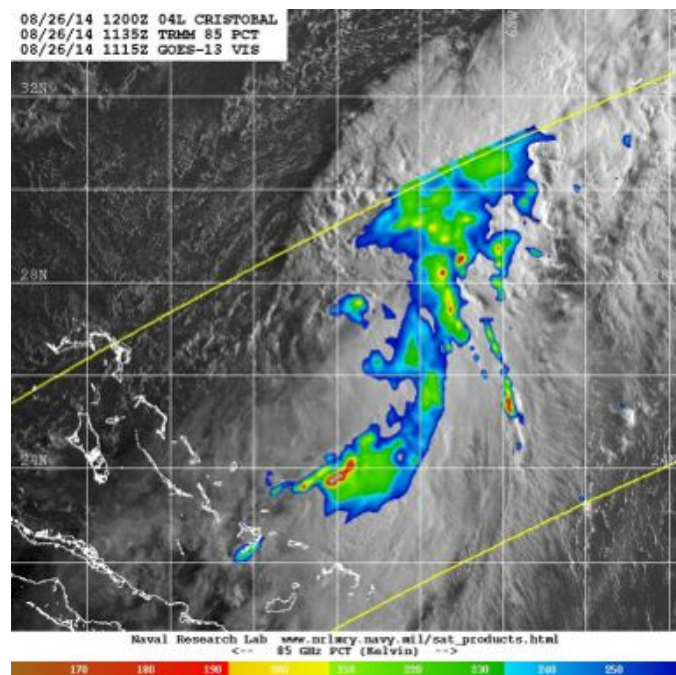


GOES Cloud top heights (CTHs) at 1145 UTC. Cristobal has been moving more slowly than forecasted, so the pattern will likely need to be shifted southward toward the Bahamas. CTHs generally exceed 52 kft.



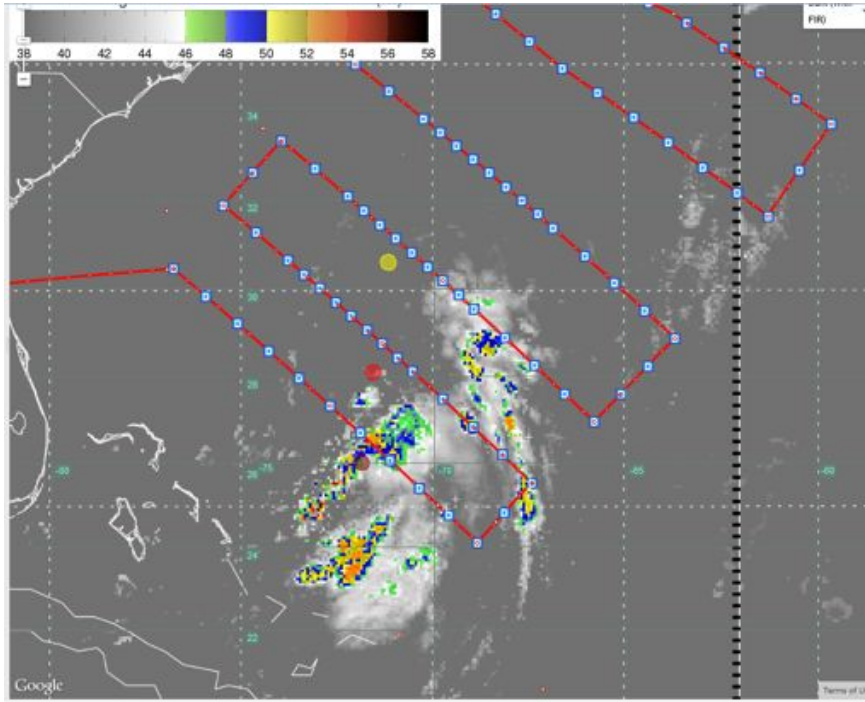
GOES IR and upper-level winds show a good outflow jet to the south of Cristobal, strong SW flow to the NE that may be outflow or an enhancement of the upper-level jet stream via strong divergence from Cristobal. Below is the NHC forecast from 09UTC.

INIT	26/0900Z	26.0N	71.9W	65 KT	75 MPH	
12H	26/1800Z	28.1N	71.6W	70 KT	80 MPH	
24H	27/0600Z	30.6N	71.2W	70 KT	80 MPH	
36H	27/1800Z	32.6N	70.3W	80 KT	90 MPH	
48H	28/0600Z	35.0N	68.0W	80 KT	90 MPH	
72H	29/0600Z	41.0N	55.5W	70 KT	80 MPH	
96H	30/0600Z	48.0N	40.0W	60 KT	70 MPH	...POST-TROP/EXTRATROP
120H	31/0600Z	57.0N	30.0W	50 KT	60 MPH	...POST-TROP/EXTRATROP



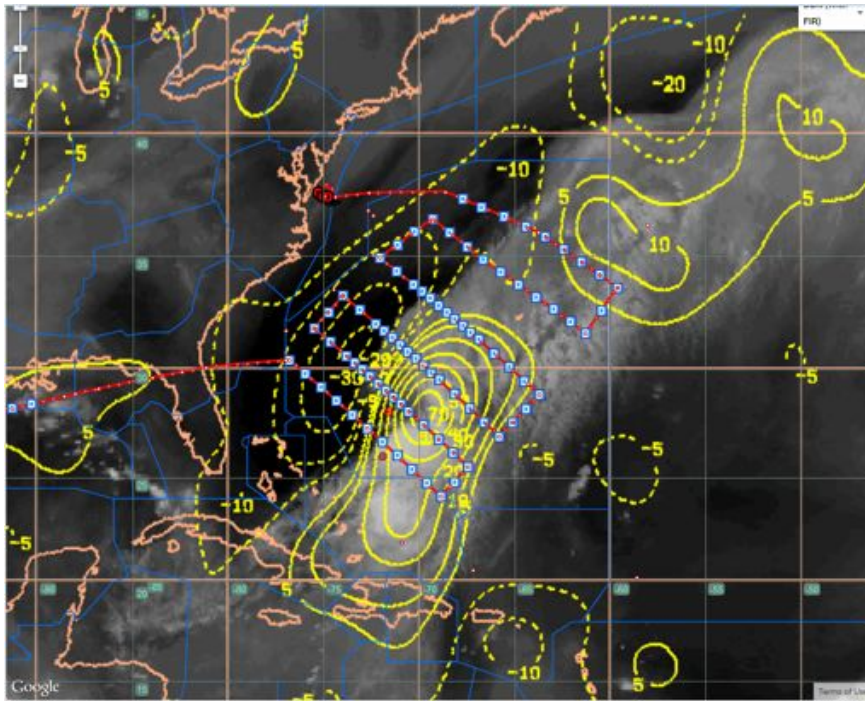
TRMM image of Cristobal at 1135Z. Extensive precipitation on the eastern side of the storm from well south to well north. The storm center is just south of the relatively small cell (near 71.6W, 27.5N) just west of the north-south oriented band.

Engine start: 1228 UTC

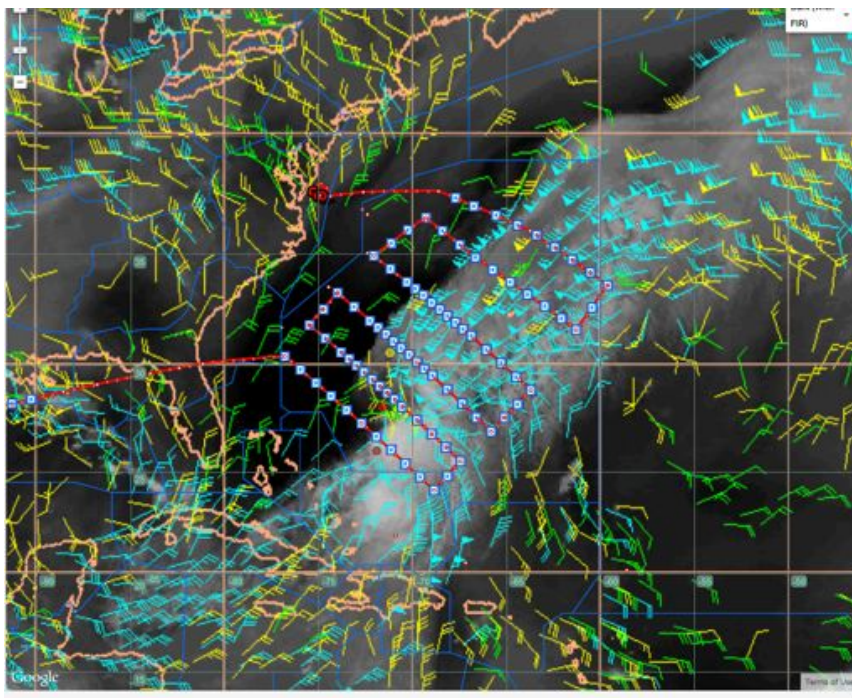


Cloud top heights diminishing quickly as convection dies off. Will likely increase again this afternoon/evening. Circles show NHC forecasted positions for Aug. 26/09Z (dark red), Aug. 26/18Z (red), and Aug. 27/06Z (yellow).





The above 12Z GOES IR and upper-level divergence. Strong divergence above the convective area and strong convergence (and likely subsidence) to its west.



12Z Upper-level winds with flight track overlaid. Circles show forecasted storm positions as mentioned above. The planned pattern will have to be shifted southward in order to get measurements within Cristobal, but we would also be sampling the outflow region to the north of the storm and its interaction with the jet.

Taxi: 1301 UTC

Takeoff: 1308 UTC

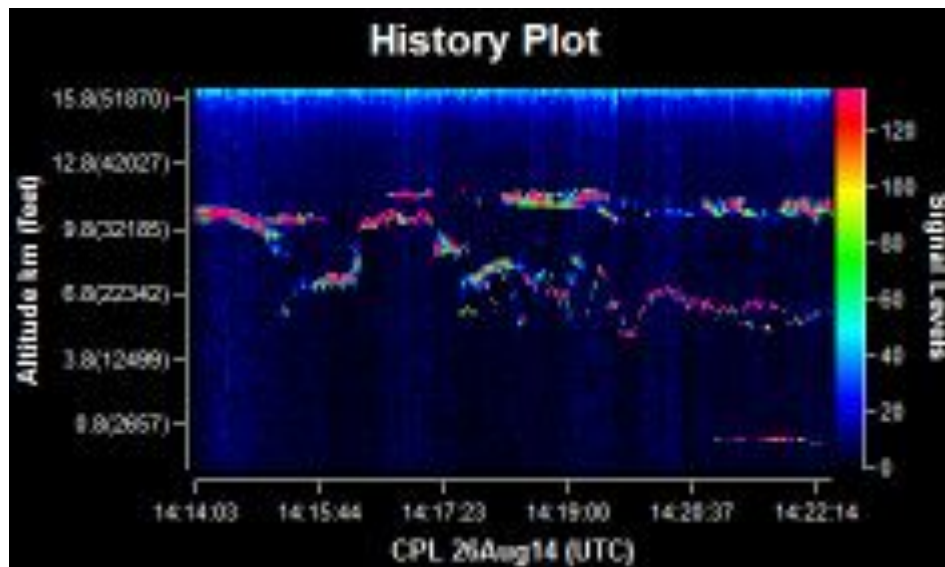
1346Z Daylight camera looking good so far. HDVIS iced over, hoping heater takes care of it. Low light camera (not shown) working, but image isn't good since we are heading toward the sun.



CPL began lasing about 1410Z.



Just passed over some shallow precipitation bands. They show up on the radar, but no sign of them in the CTH product, so they do not extend above 40kft.



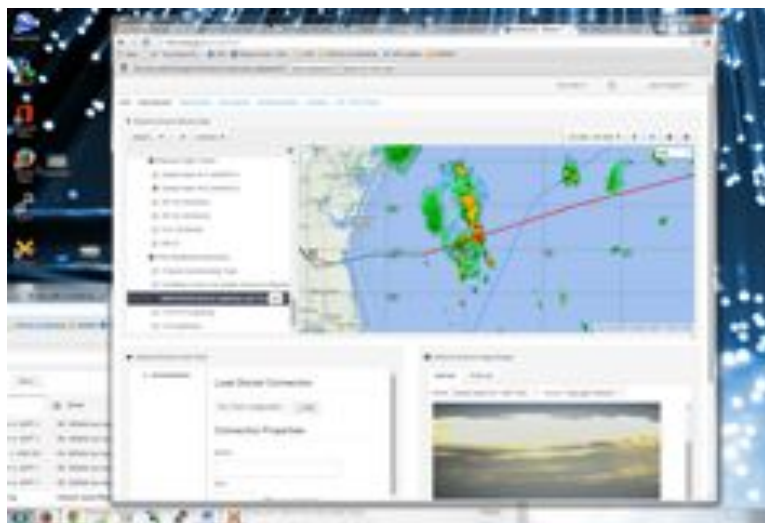
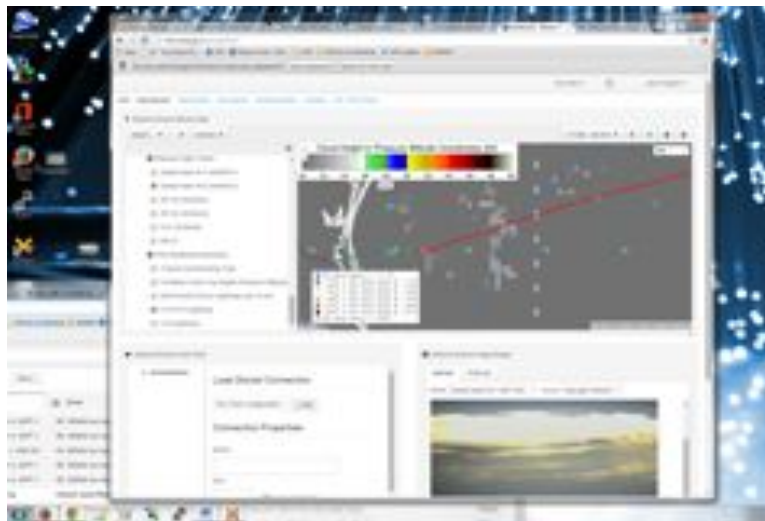
CPL image from the overflight of the precipitation bands.



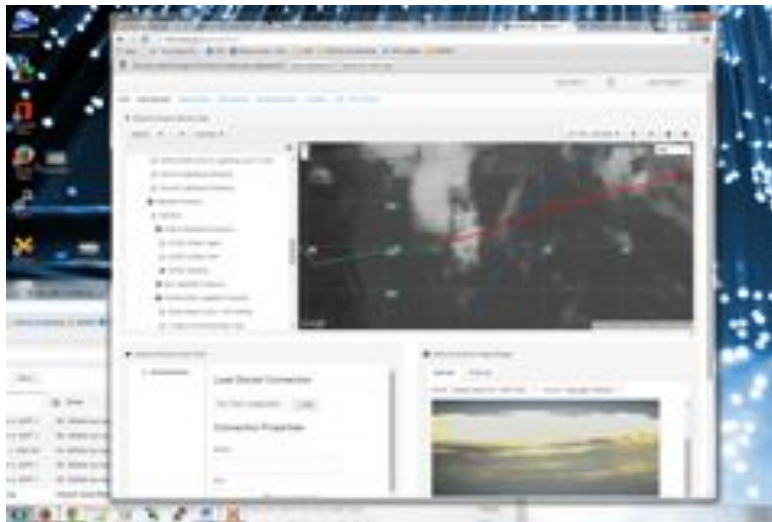
Daylight camera showing Texas coast and South Padre Island. Island visible from as far away as 100 nm, and some clouds in the distance visible as far away as 200 nm



Approaching some convection along the Texas coast about 80 NM to our ENE 17:30 UTC





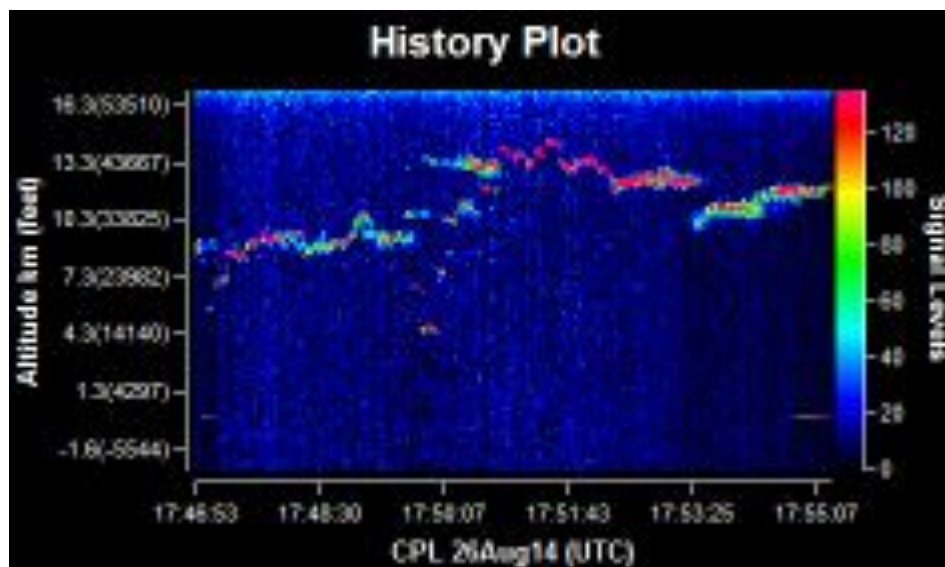
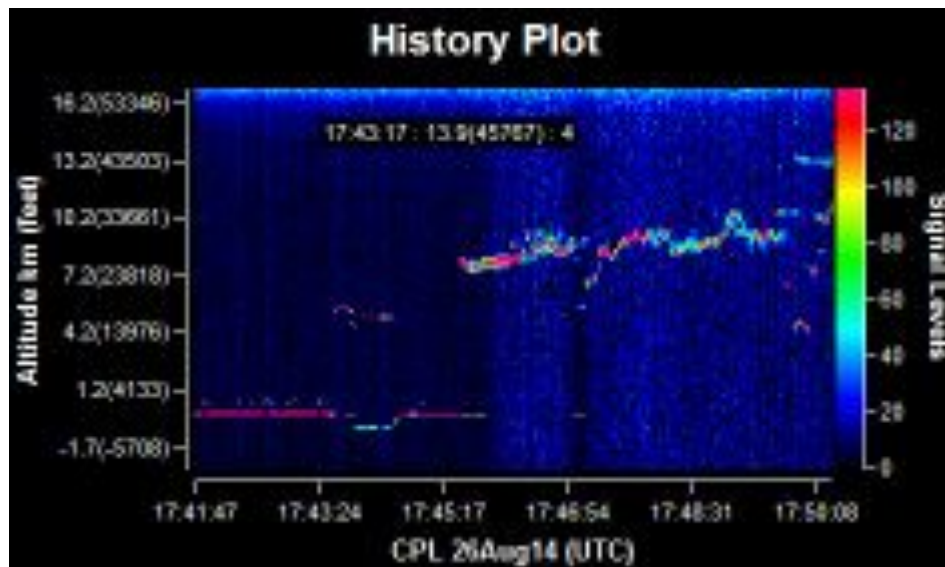


There seems to be an issue with the CTH product in the location of the clouds – radar/BT/IR all agree on location, but CTH is 30 nm too far east. What's up with this??? Time 17:45 UTC.

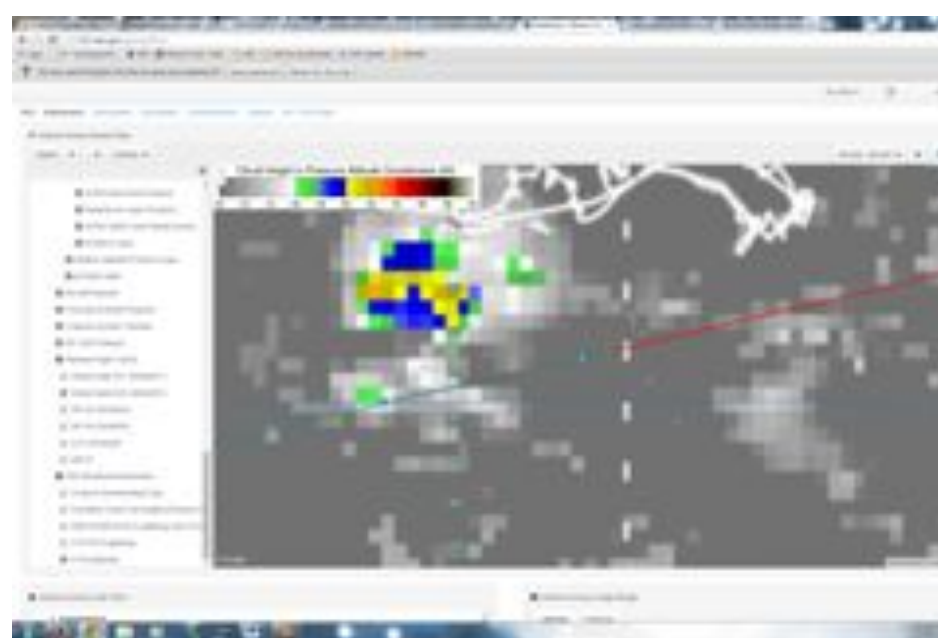


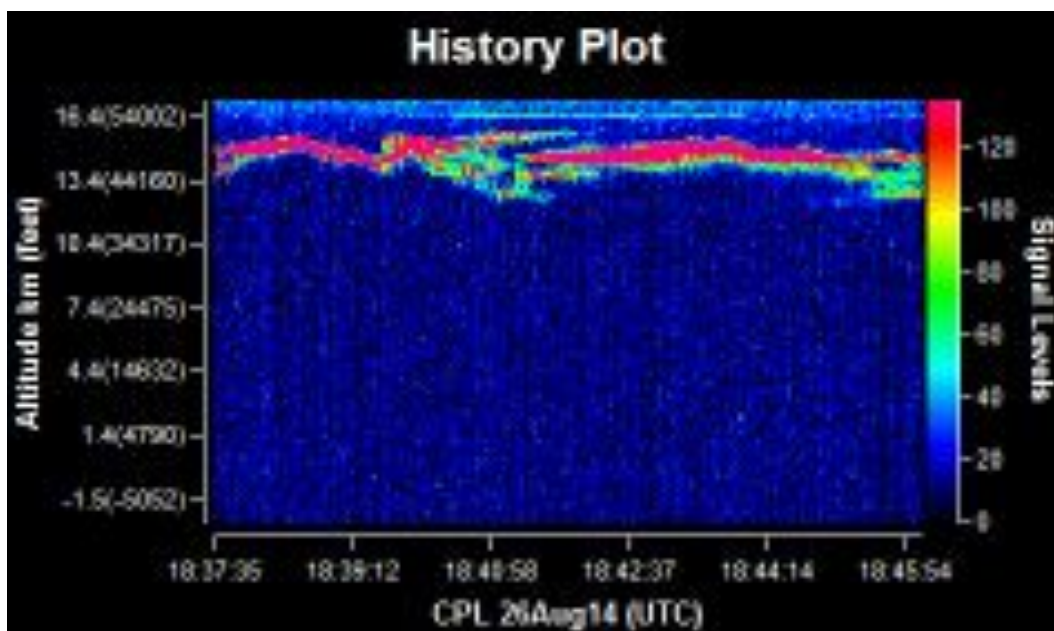


Cool images overlying convection



CPL showing tops up to 45 kft, which is in agreement with the (misplaced CTH) product





Here the CTH estimated by CPL seems to be a bit higher than that from the CTH product (a few kft difference)



We missed 2 of the first few sondes due to a problem communicating with Miami.

Drop release

#4 - 21:40

#5 – 21:53

#6 – 22:02

#7 - 22:13

#8 – 22:23

#9 – 22:34

#10 (D12) – 22:45

#11 (D13) – 22:59

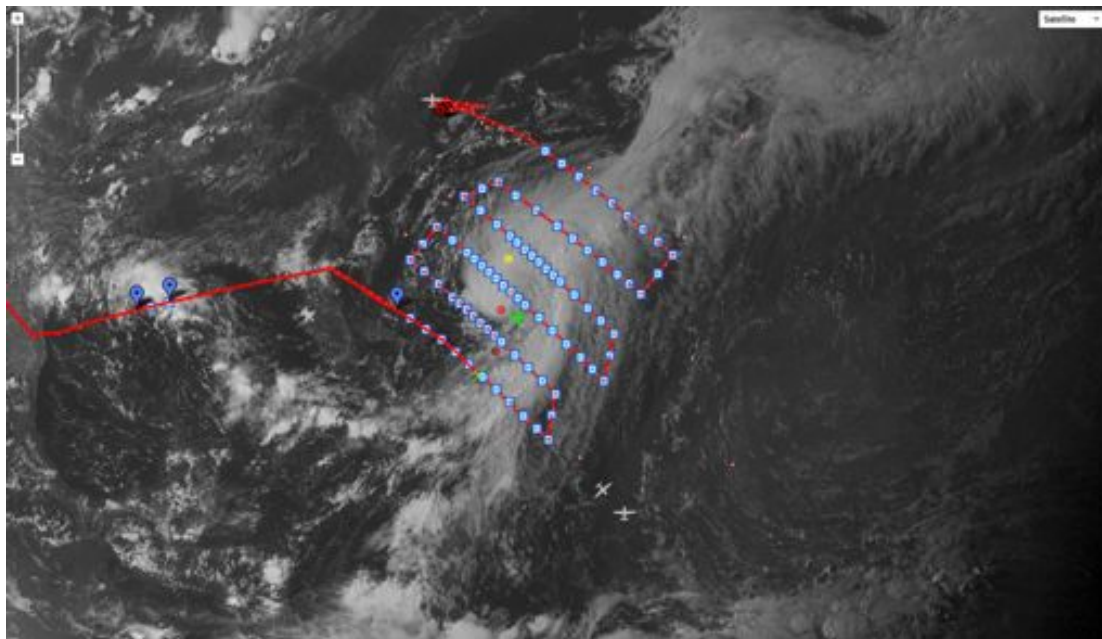
#12 (D14) – 23:07

#13 (D15) – 23:24 (some of these drops will not have data due to computer issue)

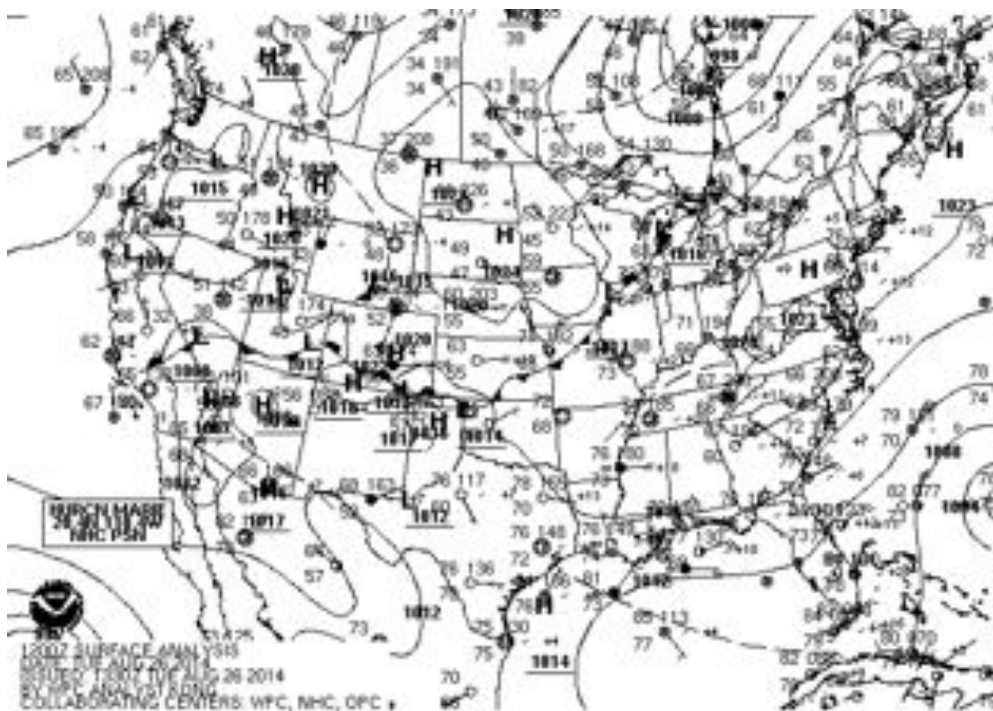
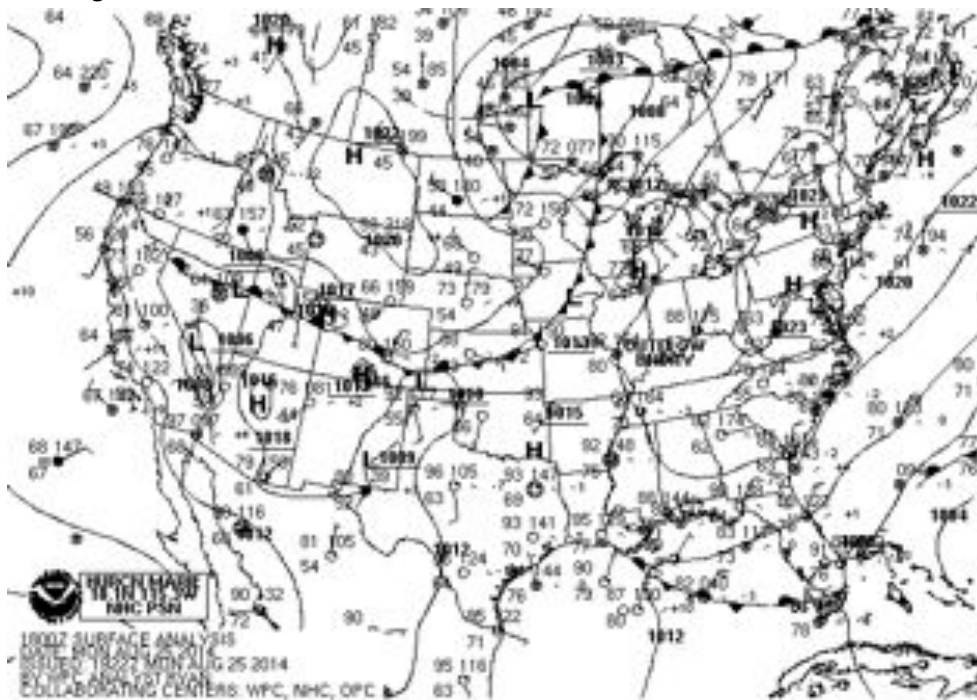
D16 skipped

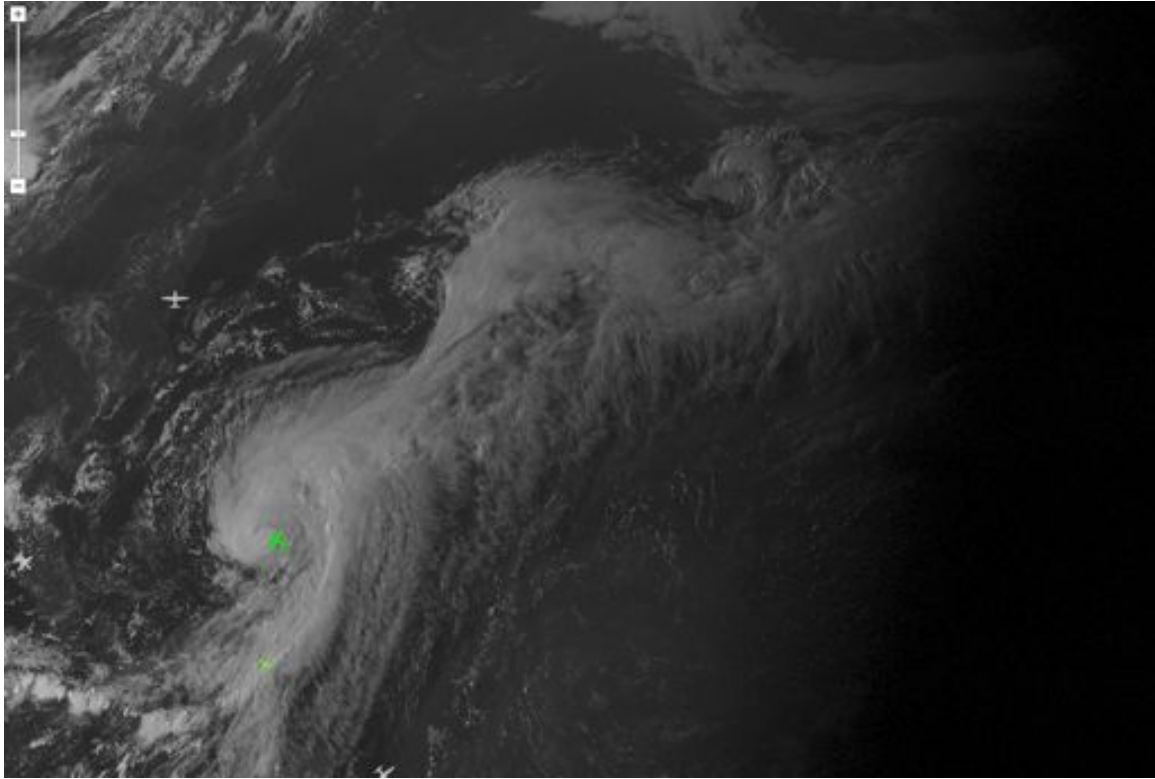
D17 skipped

#14 (D18) – 23:47

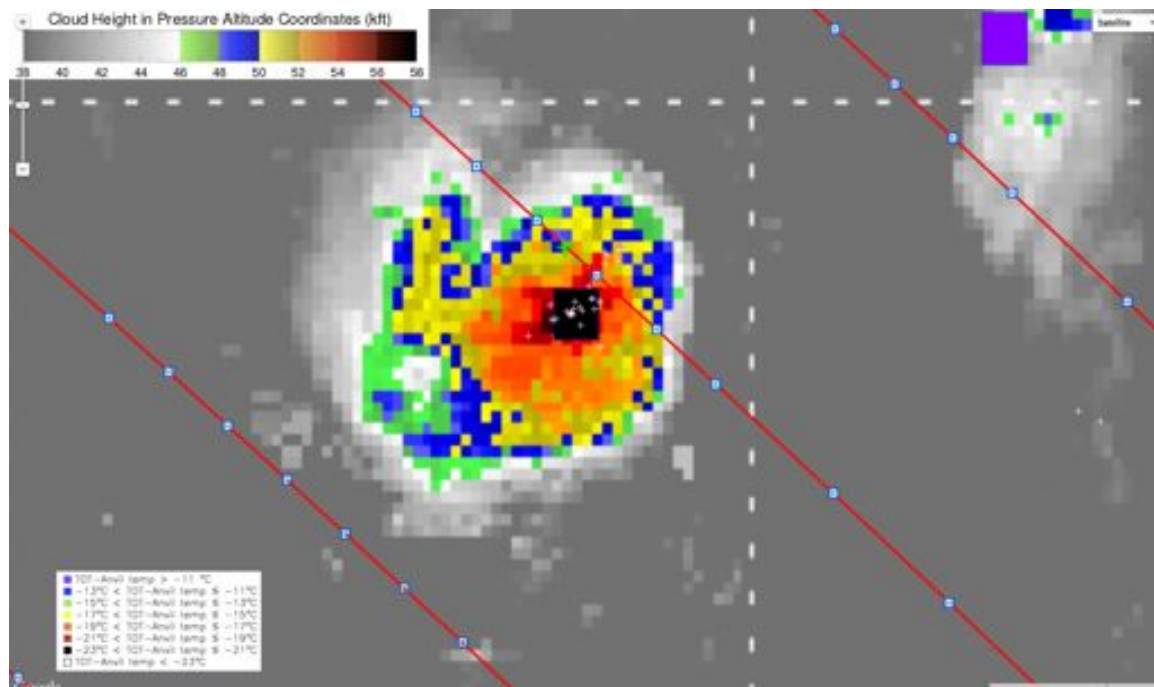


This goes image from 2200 UTC shows an arc of convection connecting Cristobal to the GOM disturbance that we dropped a few sondes into. The surface analyses from WPC (below) show the front washing out over the GOM.

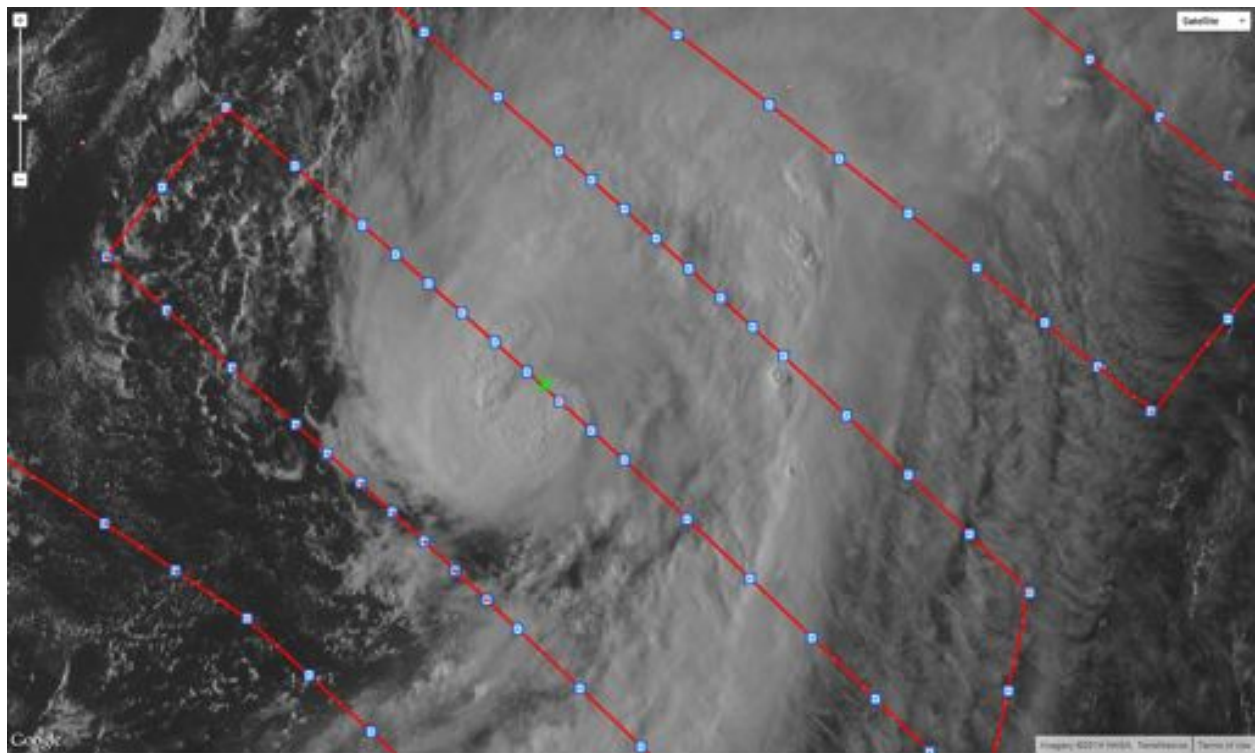




Pretty cool wave train set up along frontal boundary in NATL – Cristobal is the third, and the GOM disturbance is the 4th. 2220 UTC.

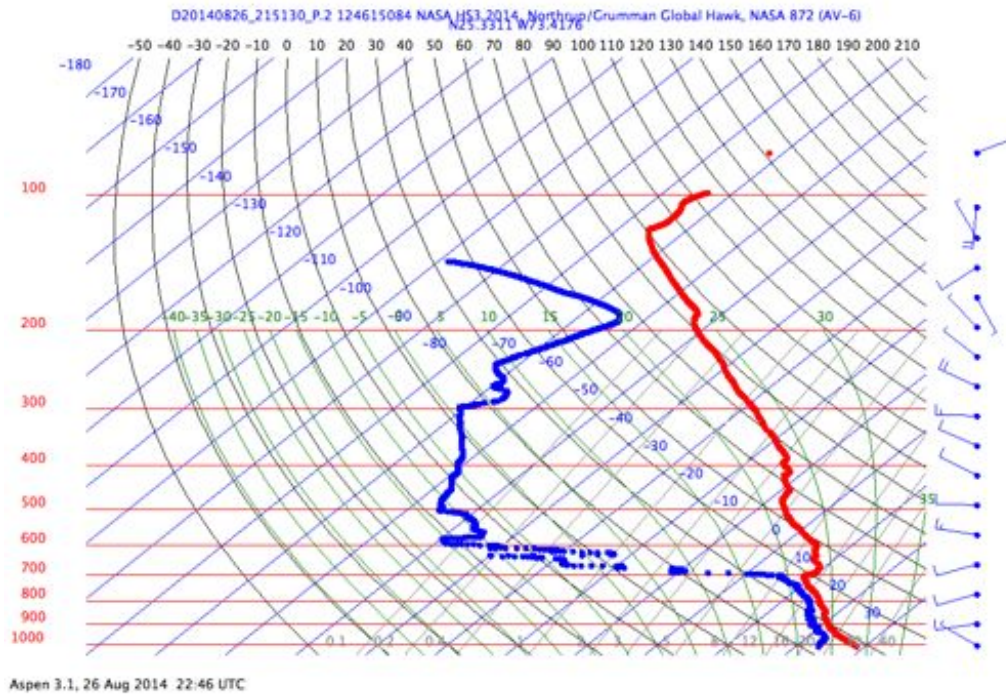


Very cold CT with a bunch of lightning. Qualifies as significant convective cloud tops that we'll have to avoid later.



One of last vis shots of day, 22:36 UTC





Sondes showing very dry airmass aloft right up to frontal boundary to south of Cristobal

Shift change...Steve Guimond taking over and logging dropsondes, etc.

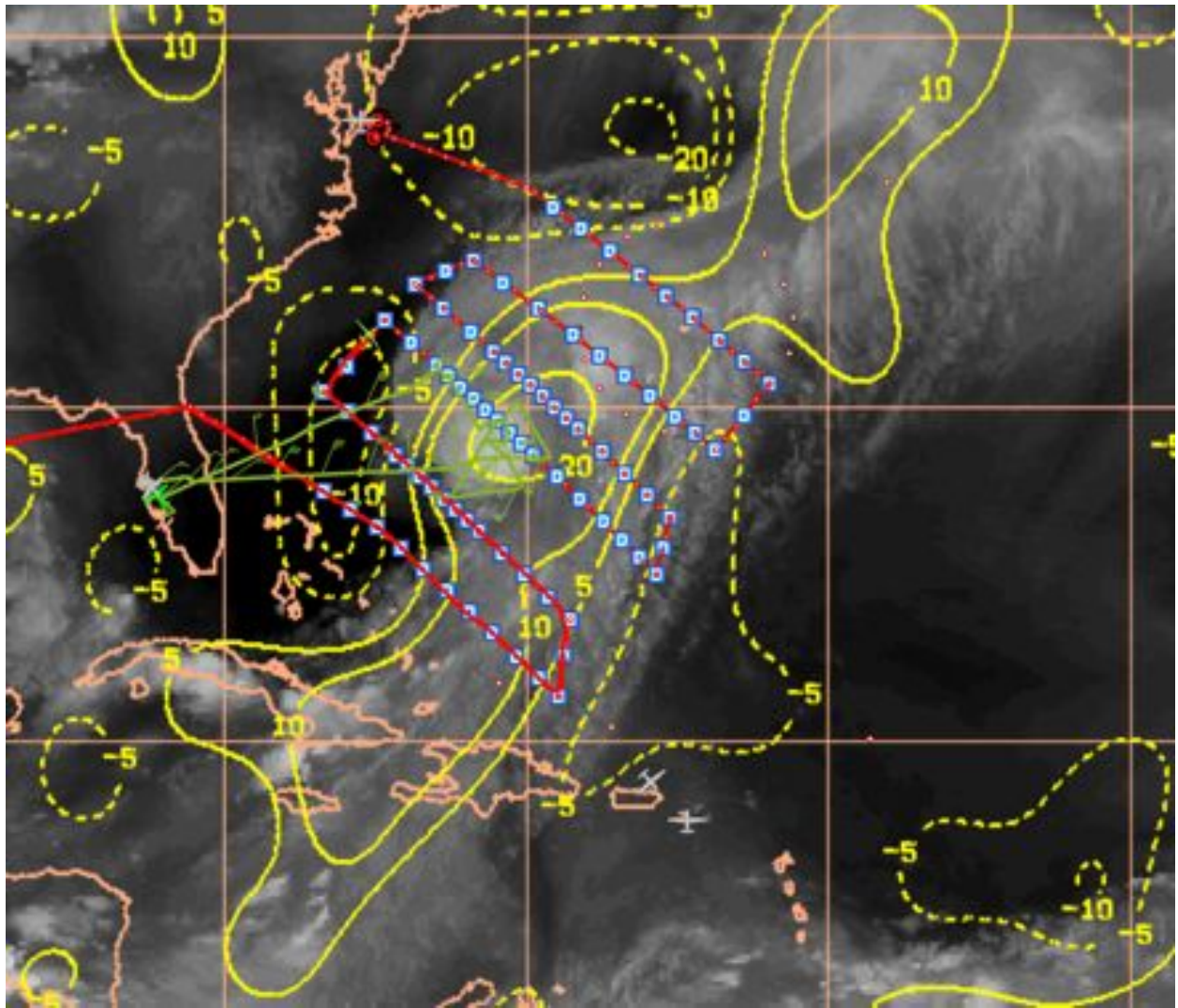
Drop #22 (D28): 0049 Z, good drop

Drop #23 (D29): 0101 Z, good drop

Drop #24 (D30): 0107 Z, good drop

Shifted track to catch the apparent center of Cristobal and GH is heading towards turn to go down that path. We are adding three extra sondes near where we think the center is. The density will be 2.5 minutes across the center.

0000 UTC upper level divergence from CIMSS product (below) shows decent core of divergence over Cristobal so upper level environment is favorable.

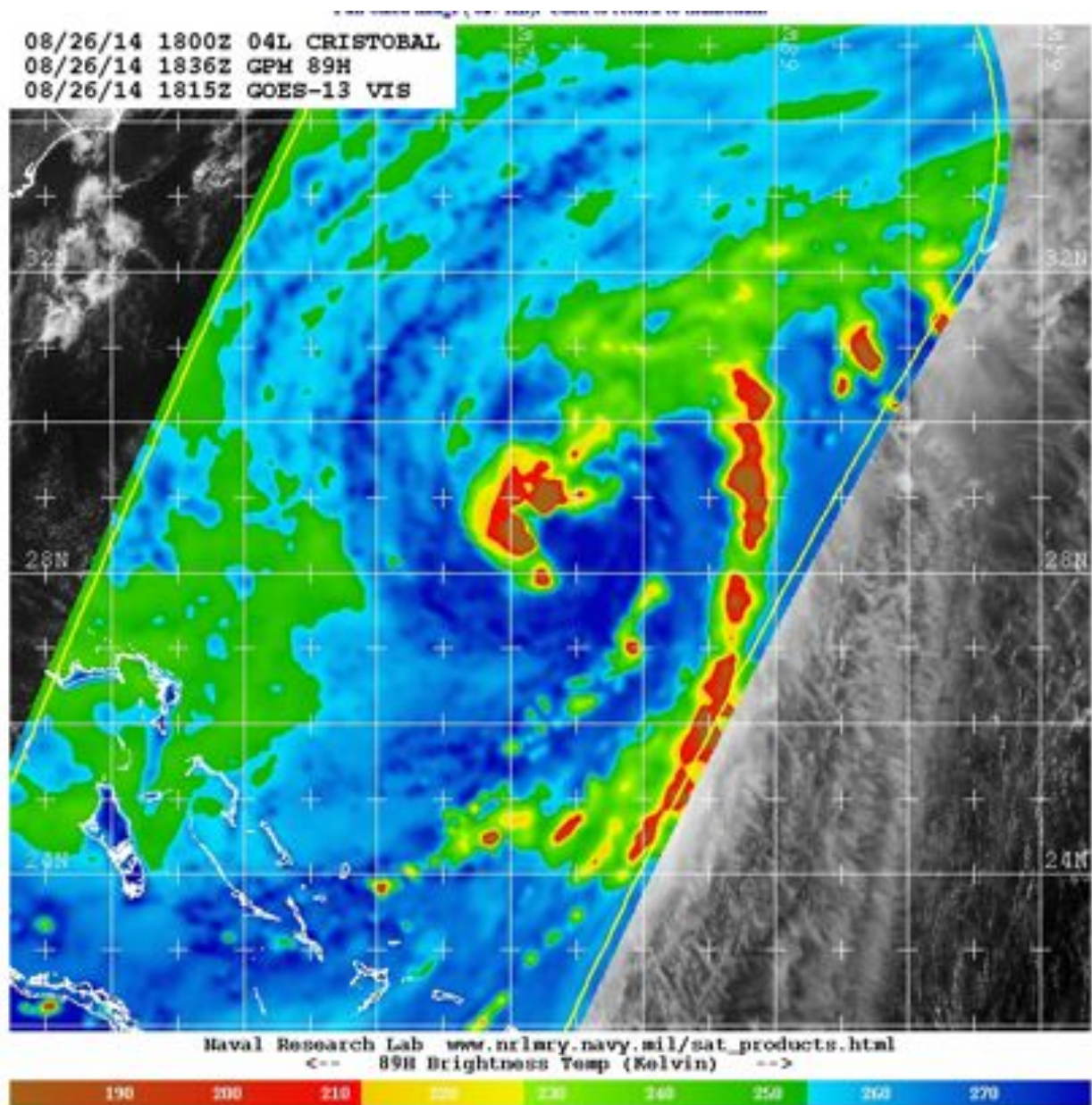


Drop #25 (D31): 0127 Z, good drop

Drop #26 (D32): 0135 Z, might have been a failed sonde, but no sonde in tube so assuming its okay but no notification yet.

Ku satellite communications has been spotty in here so confirmation on drops has been slow.





GPM overpass of Cristobal from earlier showing asymmetric inner core along with what appears to be frontal convection trailing away from the storm. The inner core convection was fairly strong here and the storm was slowly strengthening.

Drop #27 (D33): 0144 Z, good sonde

Drop #28 (D34): 0149 Z, good sonde

Drop #29 (D35): 0154 Z, good sonde

Drop #30 (D35a): 0158 Z (first extra drop across center), good sonde

Drop #31 (D36): 0201 Z, good sonde

Drop #32 (D36a): 0204 Z (second extra drop across center), good sonde

Drop #33 (D37): 0207 Z, good sonde

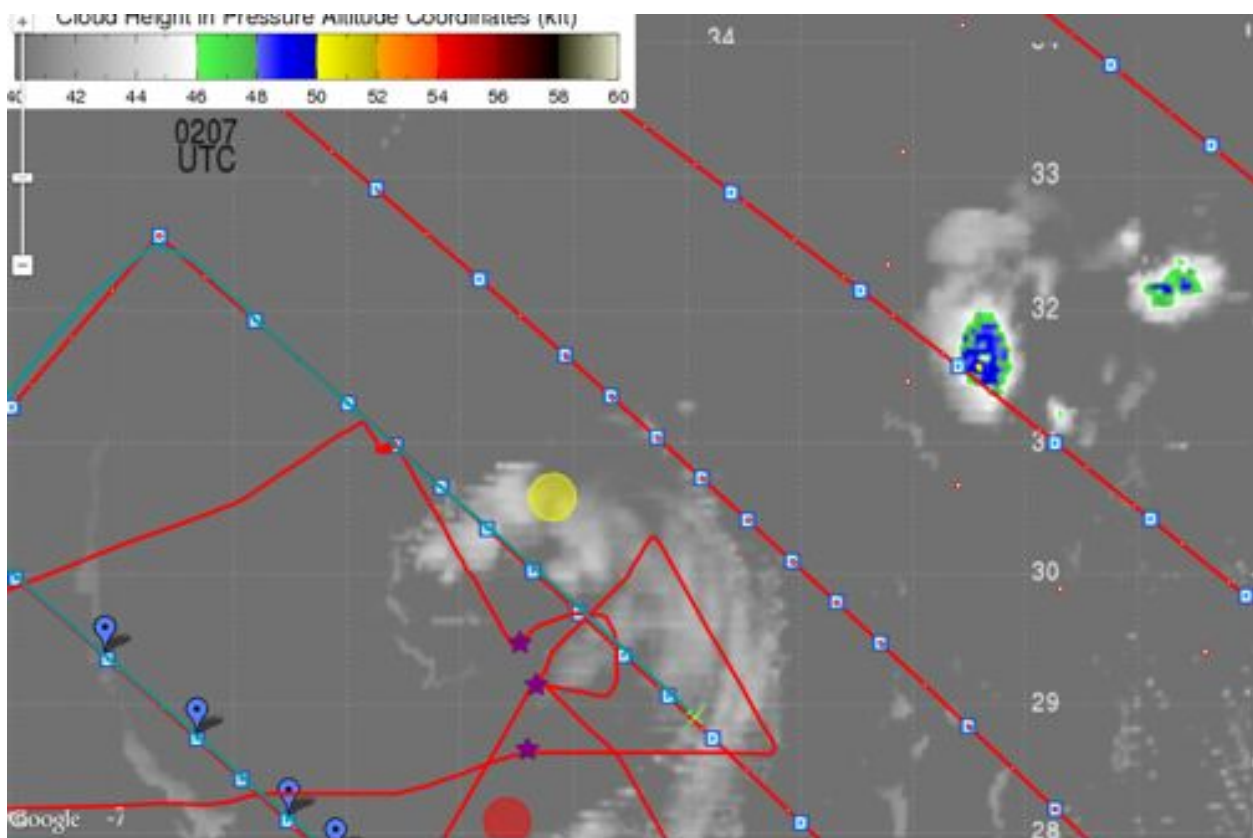
Drop #34 (D37a): 0209 Z (third extra drop across center), good sonde

Drop #35 (D38): 0212 Z, good sonde

Drop #36 (D38a): 0214 Z, (fourth extra drop across center), good sonde

Drop #37 (D39): 0217 Z, good sonde

Drop #38 (D40): 0221 Z, good sonde



0207 Z image of cloud heights showing that convection has dissipated significantly in Cristobal. Will be interesting to see how the winds have responded when they get loaded in MTS.

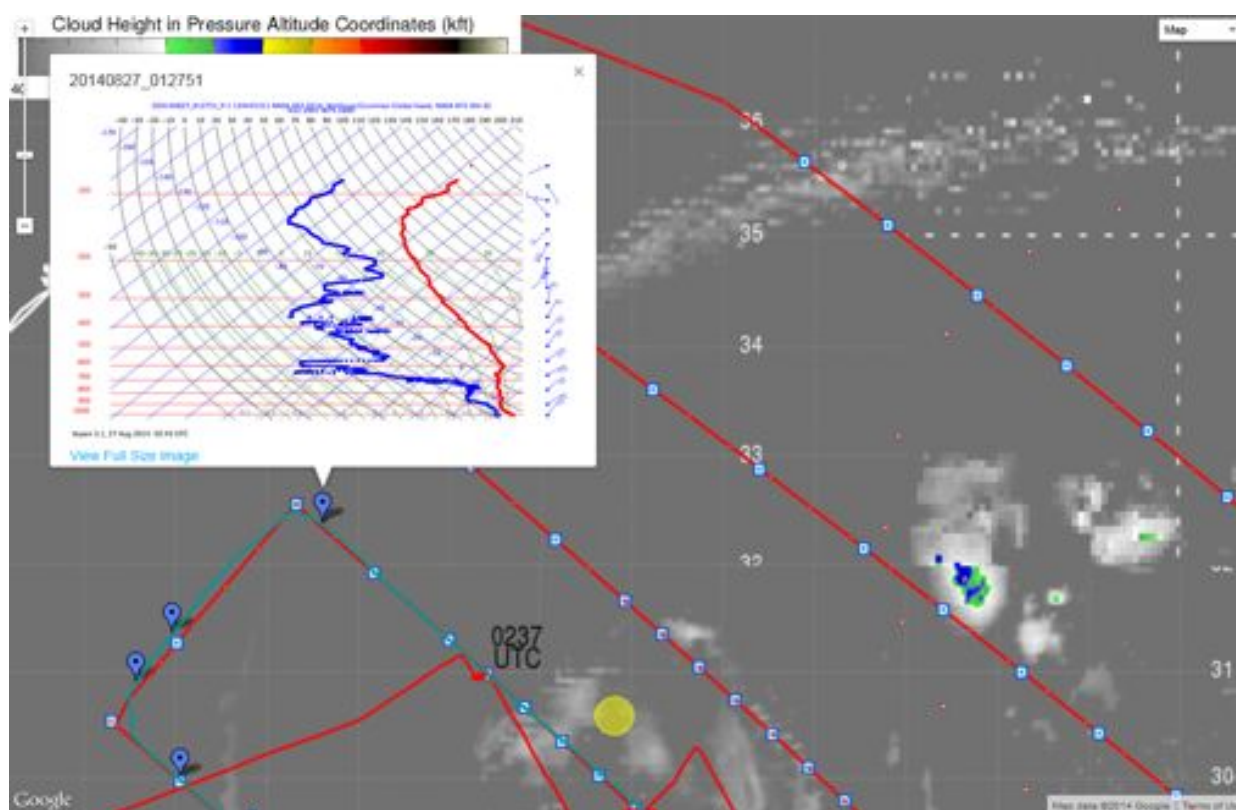


Drop #39 (D41): 0226 Z, good sonde

Drop #40 (D42): 0237 Z, good sonde

Drop #41 (D43): 0247 Z, good sonde

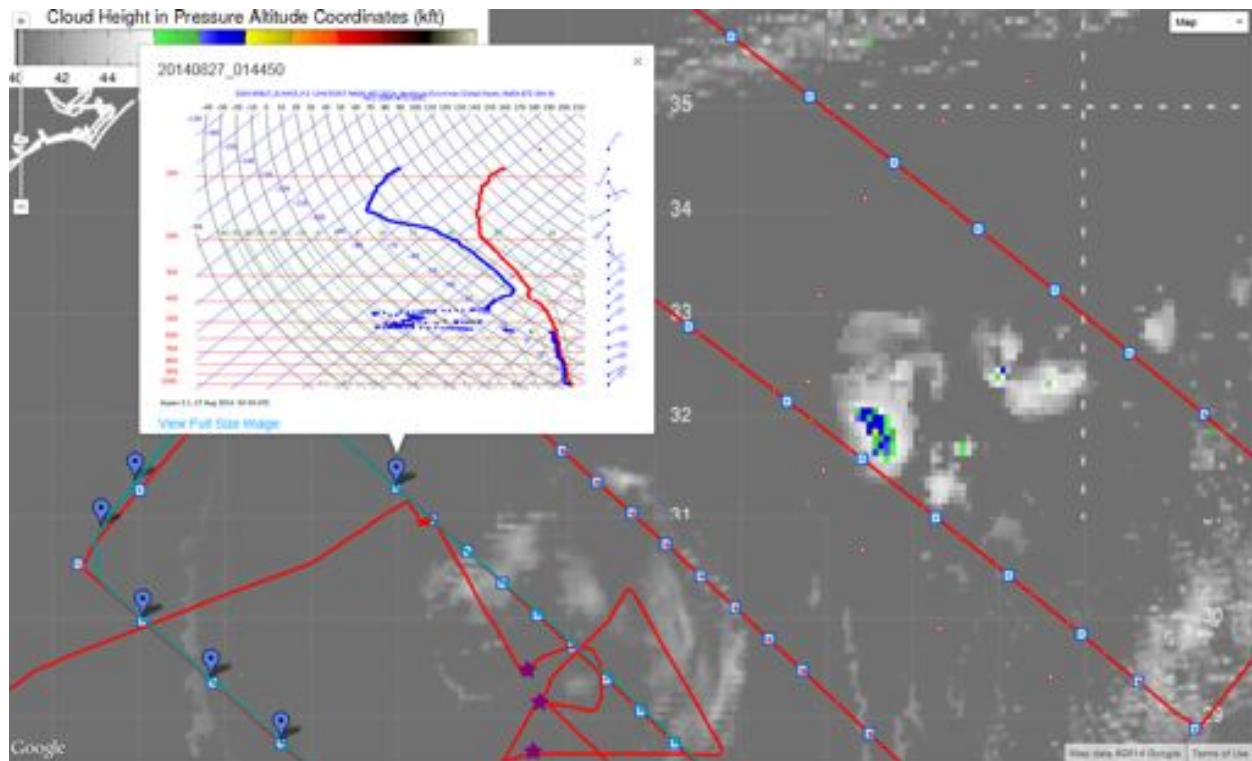
Drop #42 (D44): 0257 Z, good sonde



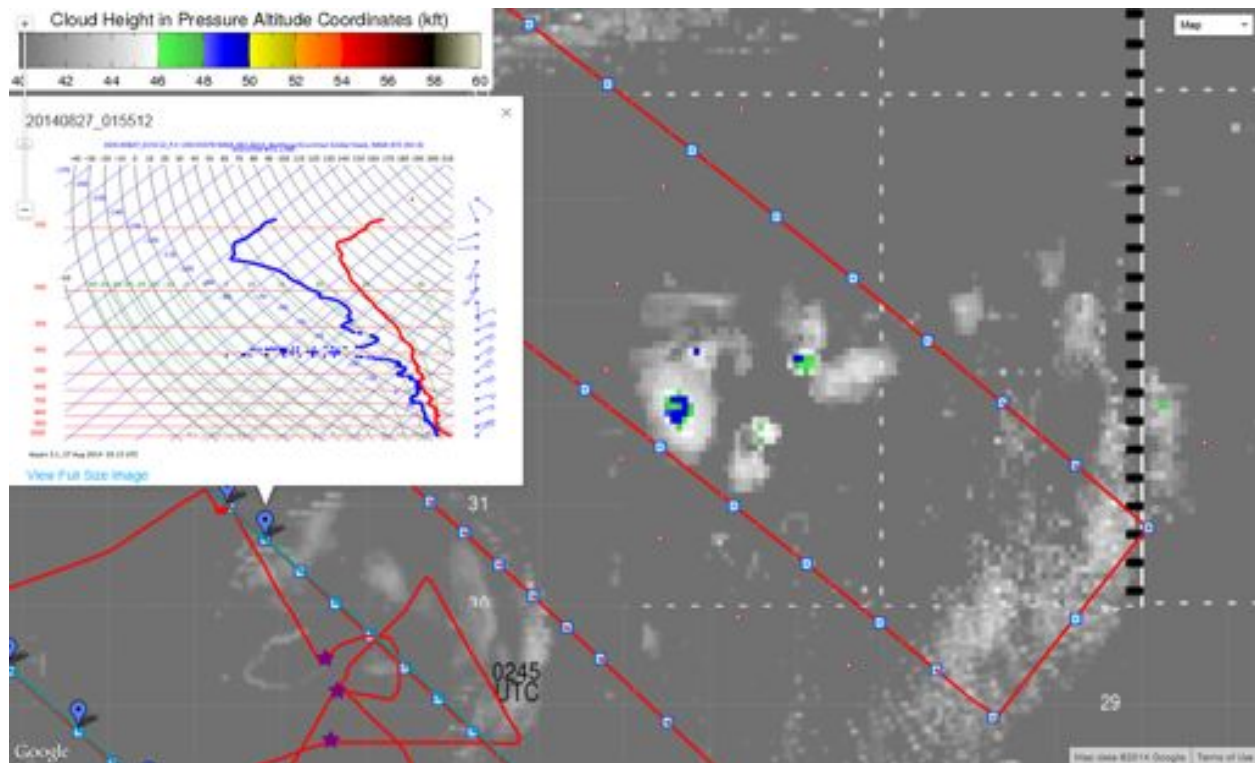
Here is the skew-T for the first dropsonde on the leg that attempted to go across the center of Cristobal. It shows very dry air especially above 800 hPa. Cristobal is moving into this environment so perhaps this is part of the reason for the depletion in convection. Since the core of Cristobal is open to the environment rather than closed off, it is not as self-sustained environment for convection.

Drop #43 (D45): 0305 Z, good sonde

Drop #44 (D46): 0313 Z, good sonde

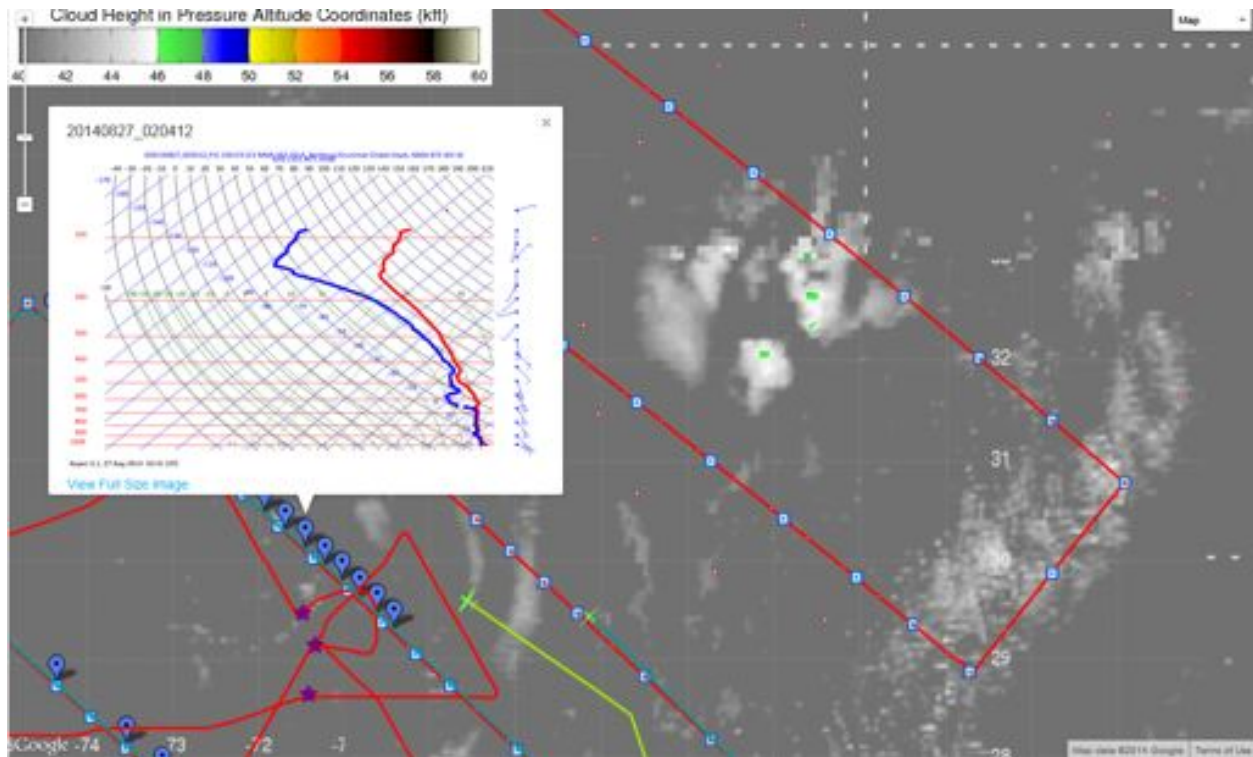


Skew-T for the second dropsonde along the center transit. This sonde is significantly more moist with a saturated lower to mid level (up to 550 hPa), a dry slot above this and then more moist compared to the last sonde.



Skew-T for the fourth dropsonde along the center transit. This sonde is similar to the last one in terms of thermodynamic structure, but the winds have increased significantly over a deep layer as we approach the center.

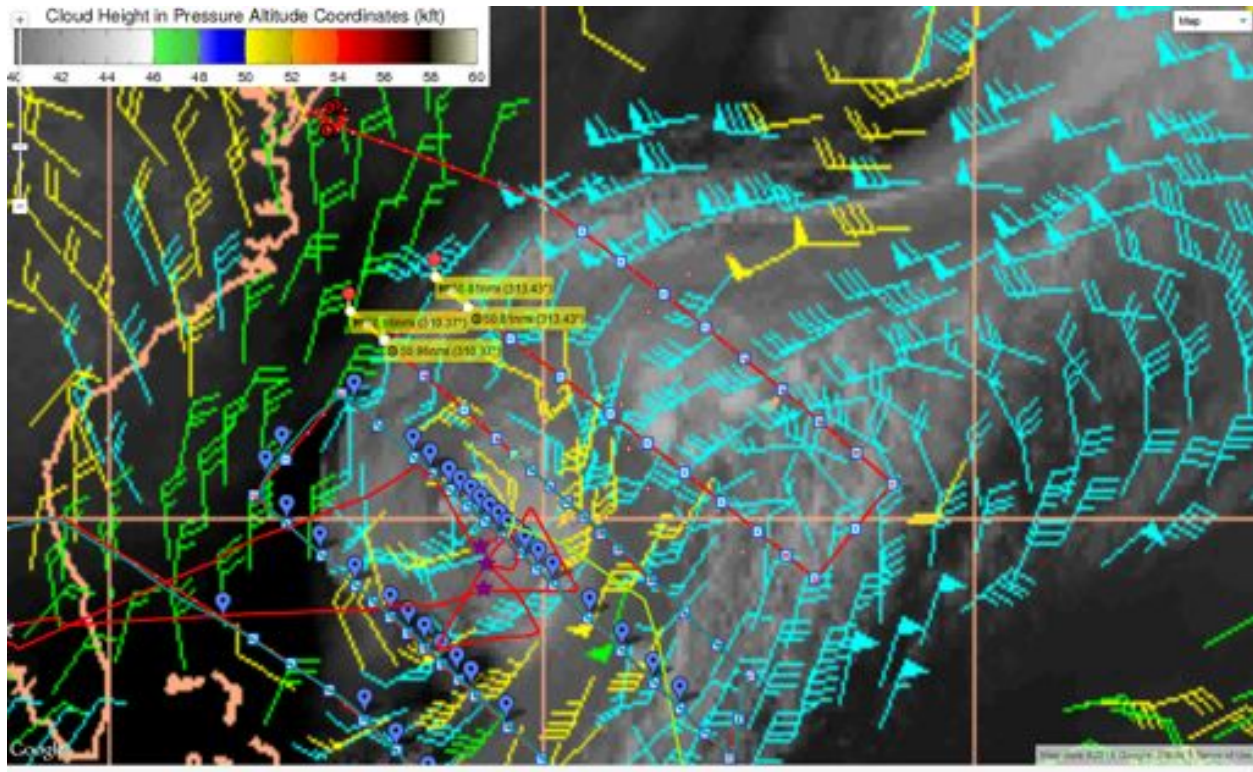
Stopped tracking sondes, payload manager has all of them anyway.

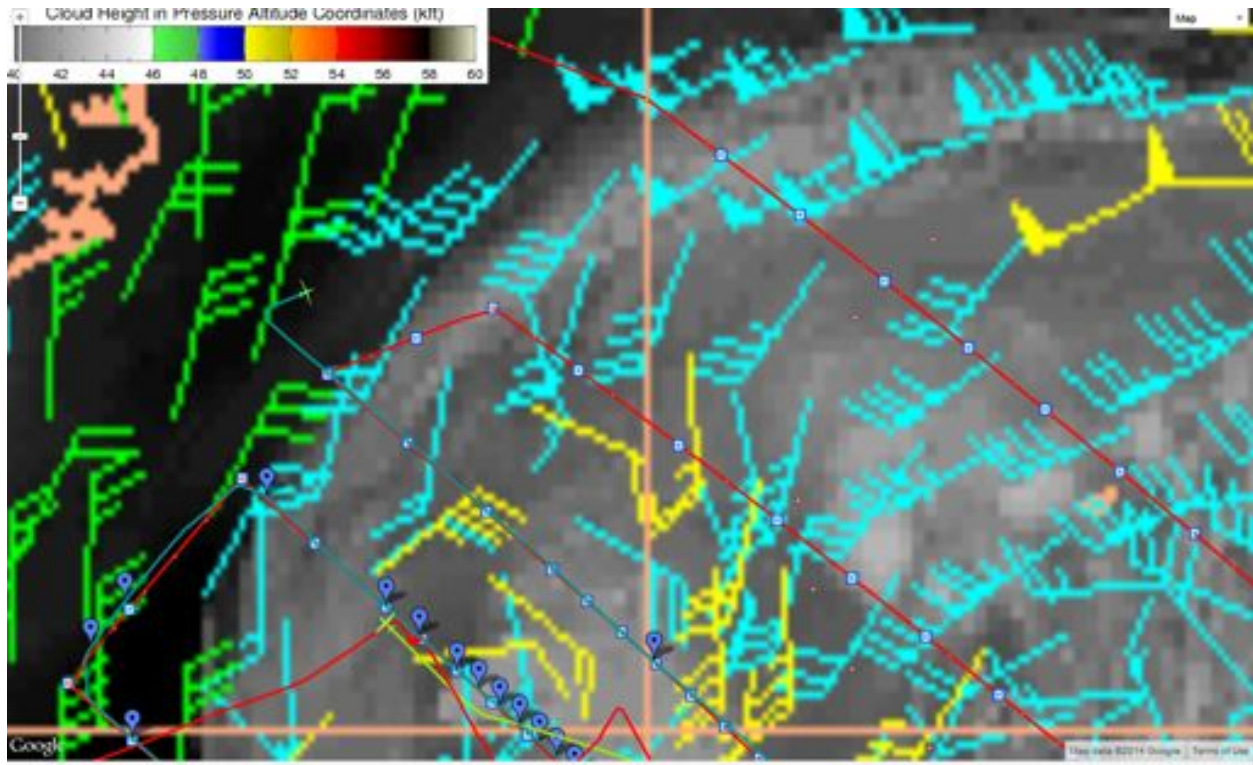


0204 Z sonde (above) had a surface pressure of 990 hPa, which was about 7 hPa higher than the last aircraft measurement. Currently an air force plane is headed towards the center to find the newest stats. The air force plane can be seen in the above image as the green line off of the red track. The GH is fairly close. The max winds seen in the GH sondes are ~ 65 kts at or below 925 hPa.

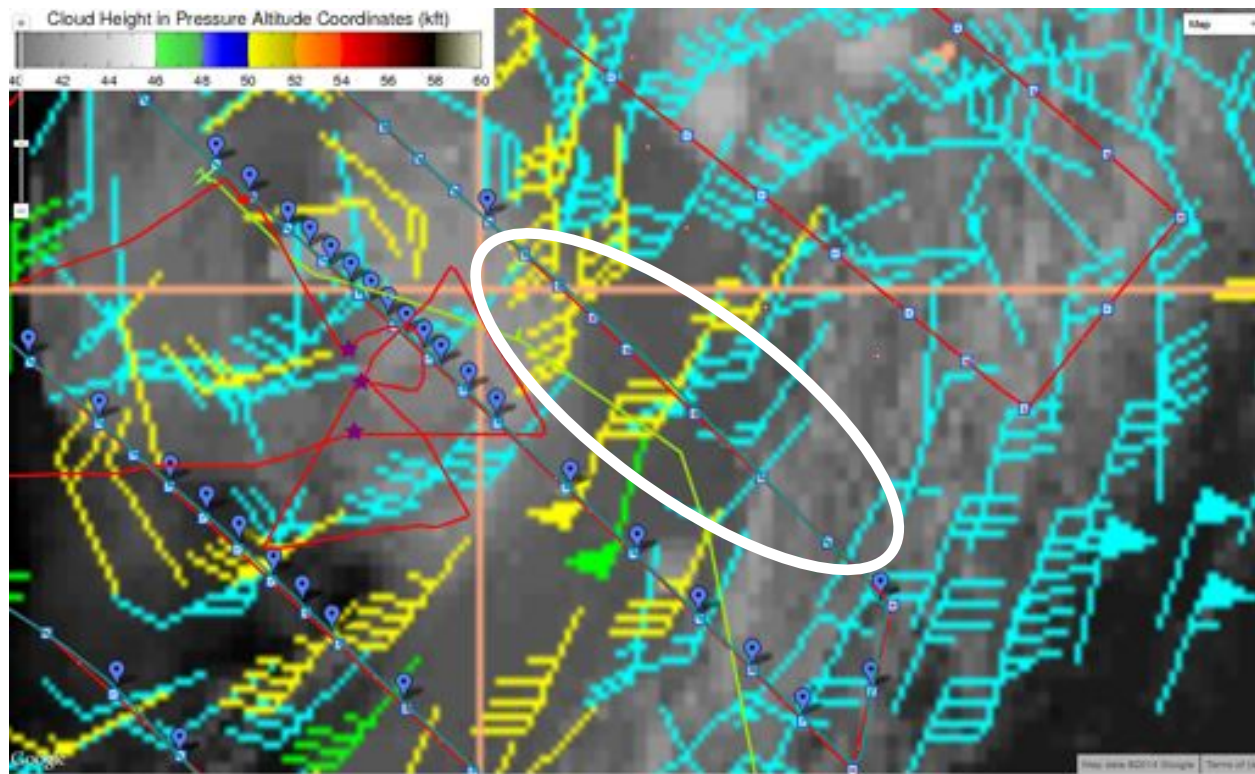


We are thinking of extending out this leg by 50 n mi to sample the gradient in winds/cloud seen in the image below. The two endpoints are shown in red and will just connect the two with the turn. We are giving these points to the pilots now. We are also thinking of adding dropsonde density through the apparent upper level outflow jet extending to the N of the center.





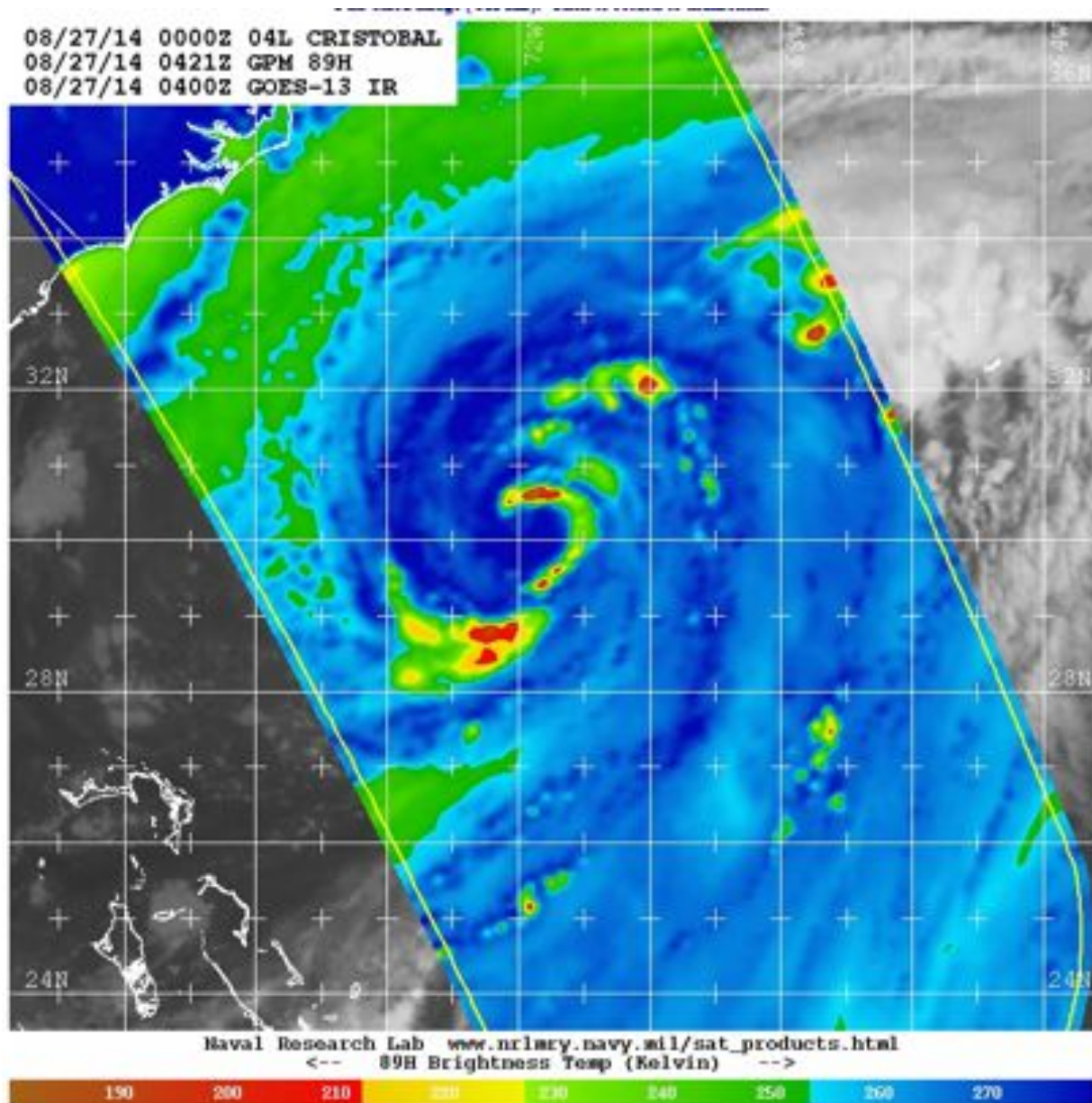
The GH is completing the 50 n mi extension and making the turn. We have added extra dropsondes to sample the apparent outflow jet seen in these CIMSS upper-level winds.



In the above circle we missed a series of sondes because a sonde got stuck in the chute. It got cleared, but there was also a pilot shift change which delayed the continuation of sondes. This occurred between 0339 and 0436 Z.

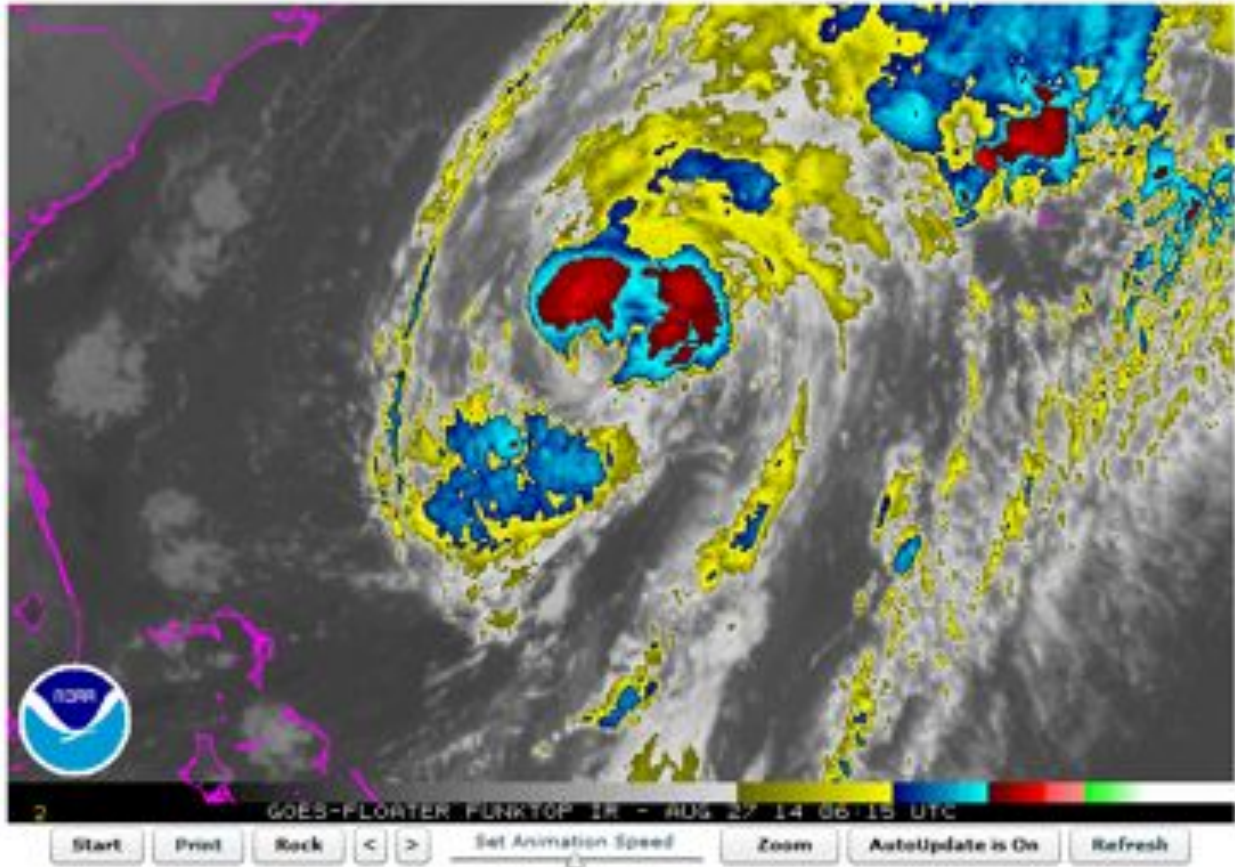
Extension of track has been uploaded in MTS via Leslie and we cut the next leg off by the same distance (50 n mi) to keep the plane landing on track.





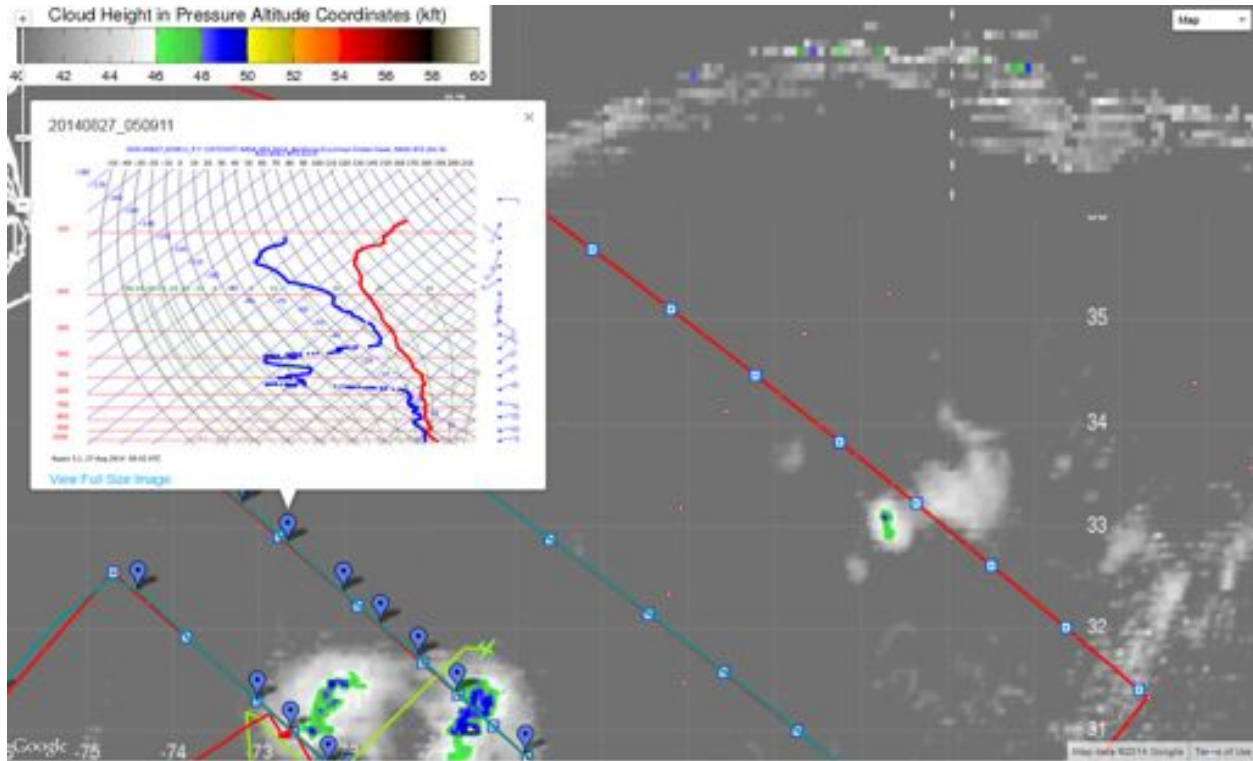
GPM overpass of Cristobal at 0421 Z showing an asymmetric inner core (similar to last pass only the convection and associated eyewall are off to the NE). The frontal convection/banding has decayed significantly. Based on the latest NHC discussion and air force flights, the system is remaining stationary and at a steady-state with minimum central pressure of 983 hPa.



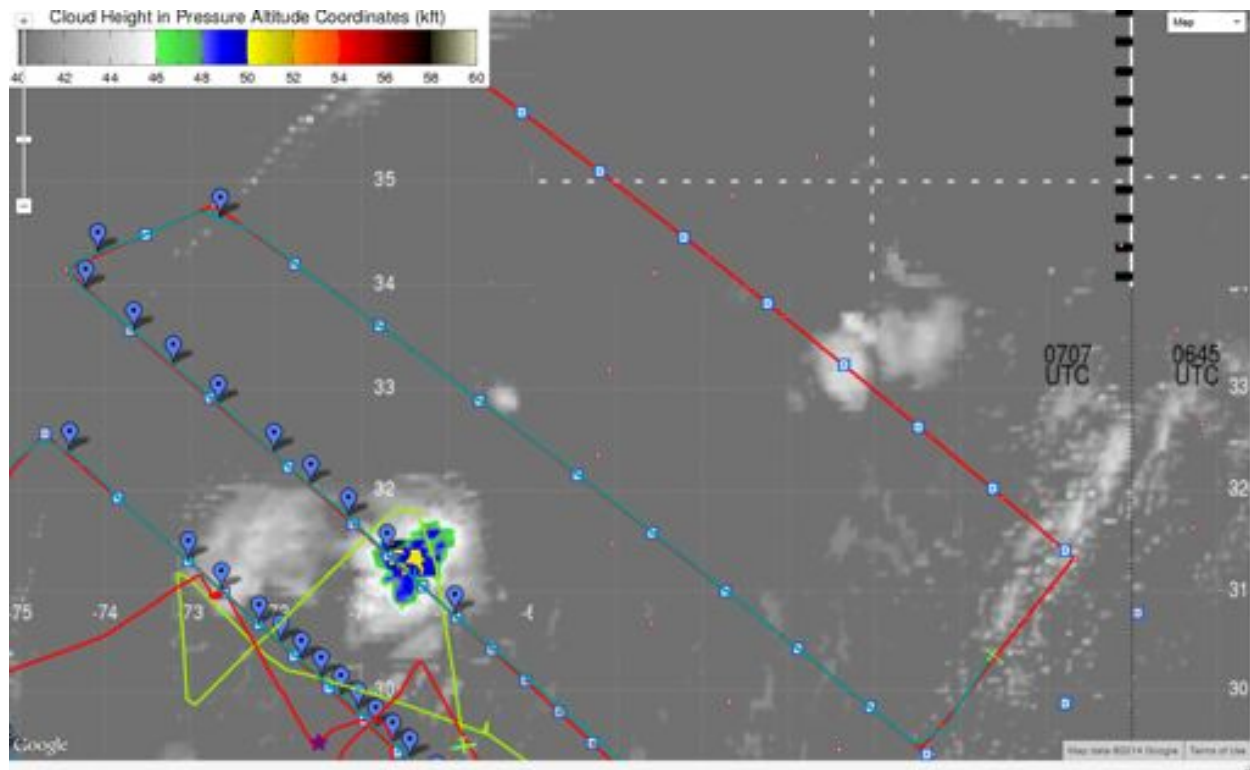


Convection in Cristobal is starting to pick up again in the northern quadrants. Also of note is the large circulation of the storm which may be due to the interaction with the mid-latitude flow. Cristobal should evolve into an excellent extratropical transition case and the broadening of the wind field is one effect of this process. Thinking ahead to the next flight with AV-6, it would be desirable to orient the legs from SW to NE to sample the interaction of the hurricane with the mid-latitude flow. It will also be interesting to study the effects of the HS3 dropsondes on the initialization of Cristobal. Studies have shown that errors in initialization of storm entering the mid-latitude flow can have drastic downstream effects due to perturbations in the Rossby wave train.

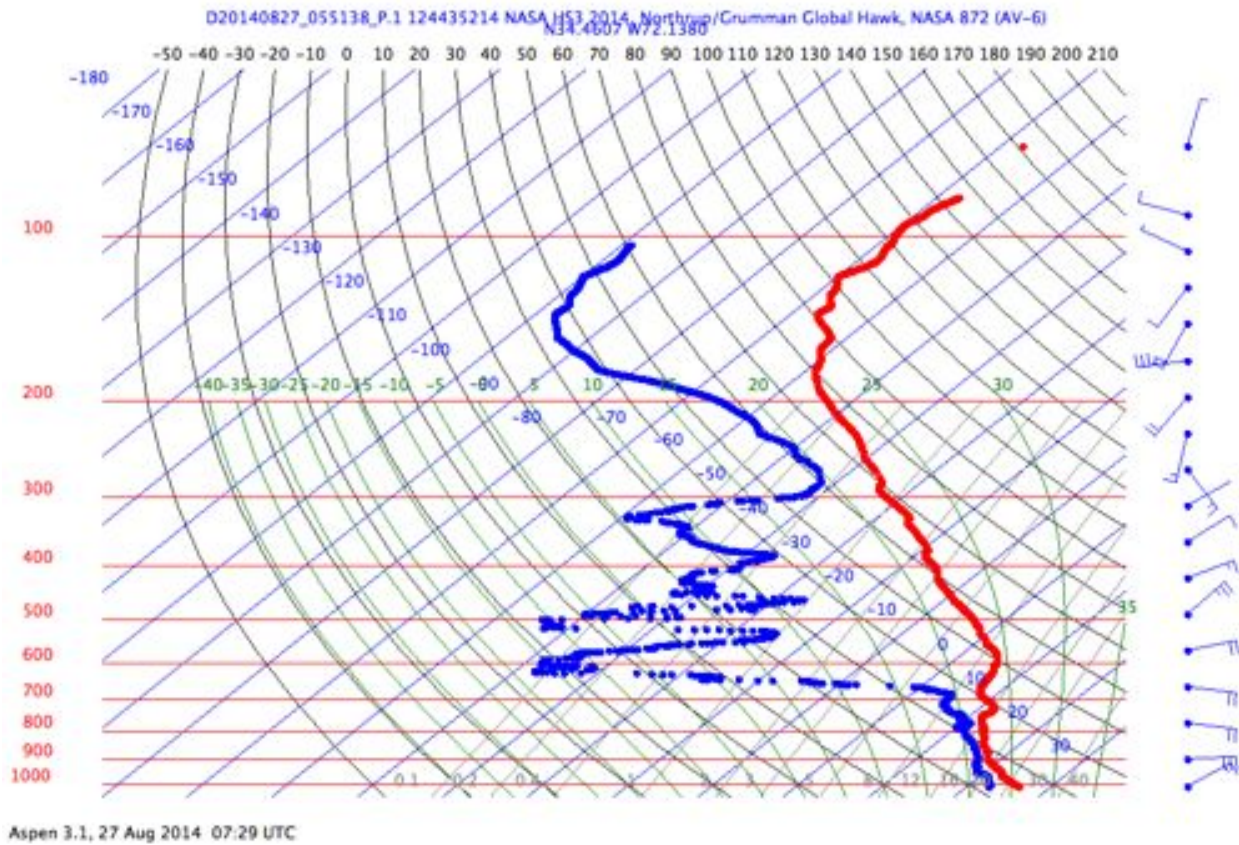
There has been some delays in processing dropsonde images so no new updates yet... Some new skew-T plots have been uploaded and one example of mid-level dry air on the edge of the system is shown below...



Very dry air slot from 550 hPa up to 350 hPa. This has been fairly common on the north and northwest sides of the system.

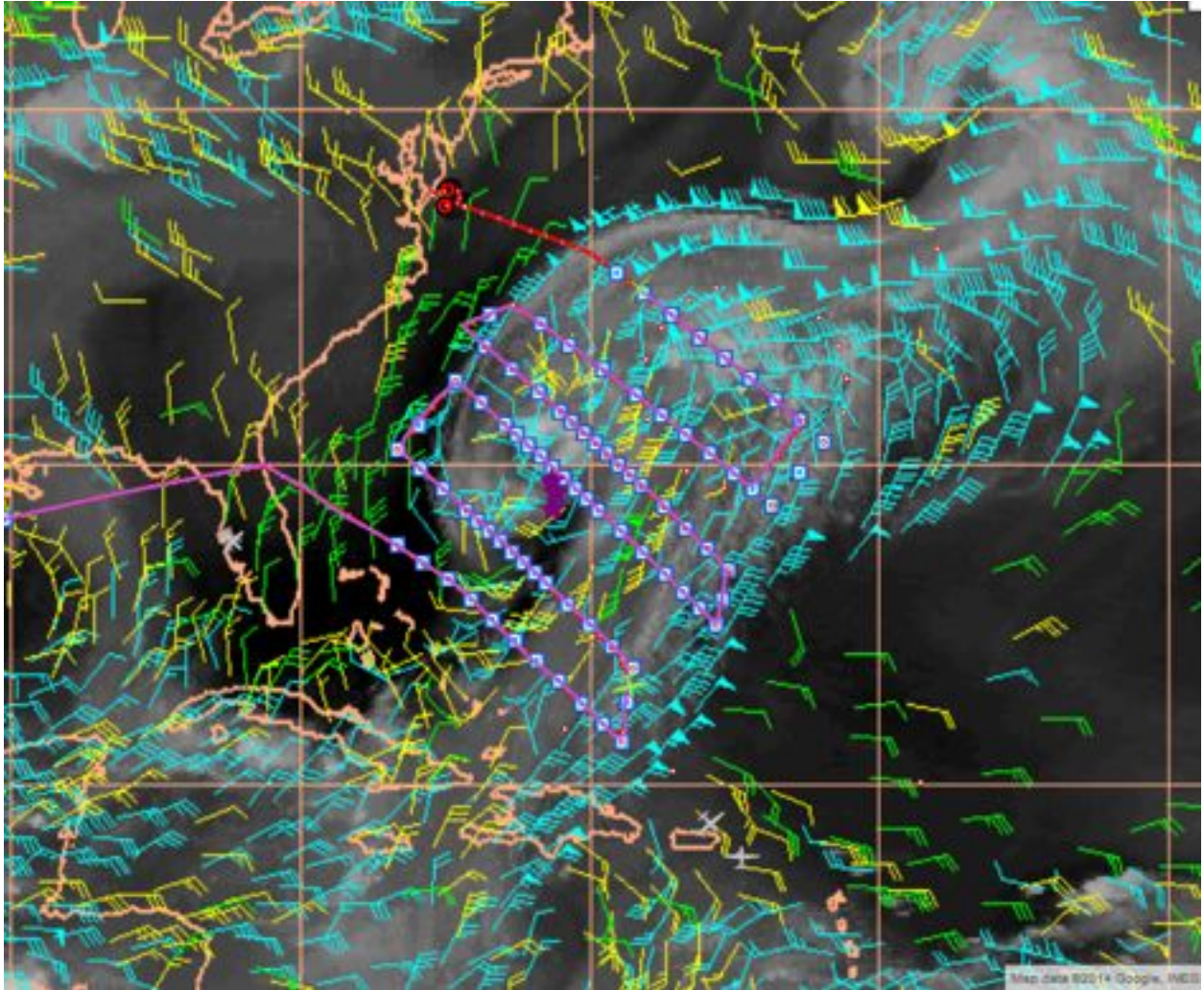


We are heading into the final leg of the flight. Waiting on a few sonde skew-Ts to show up and see if the upper-level jet was sampled by the high density drops. Deep convection is on and off near the storm core. Maybe it will pick up again once the sun comes out.

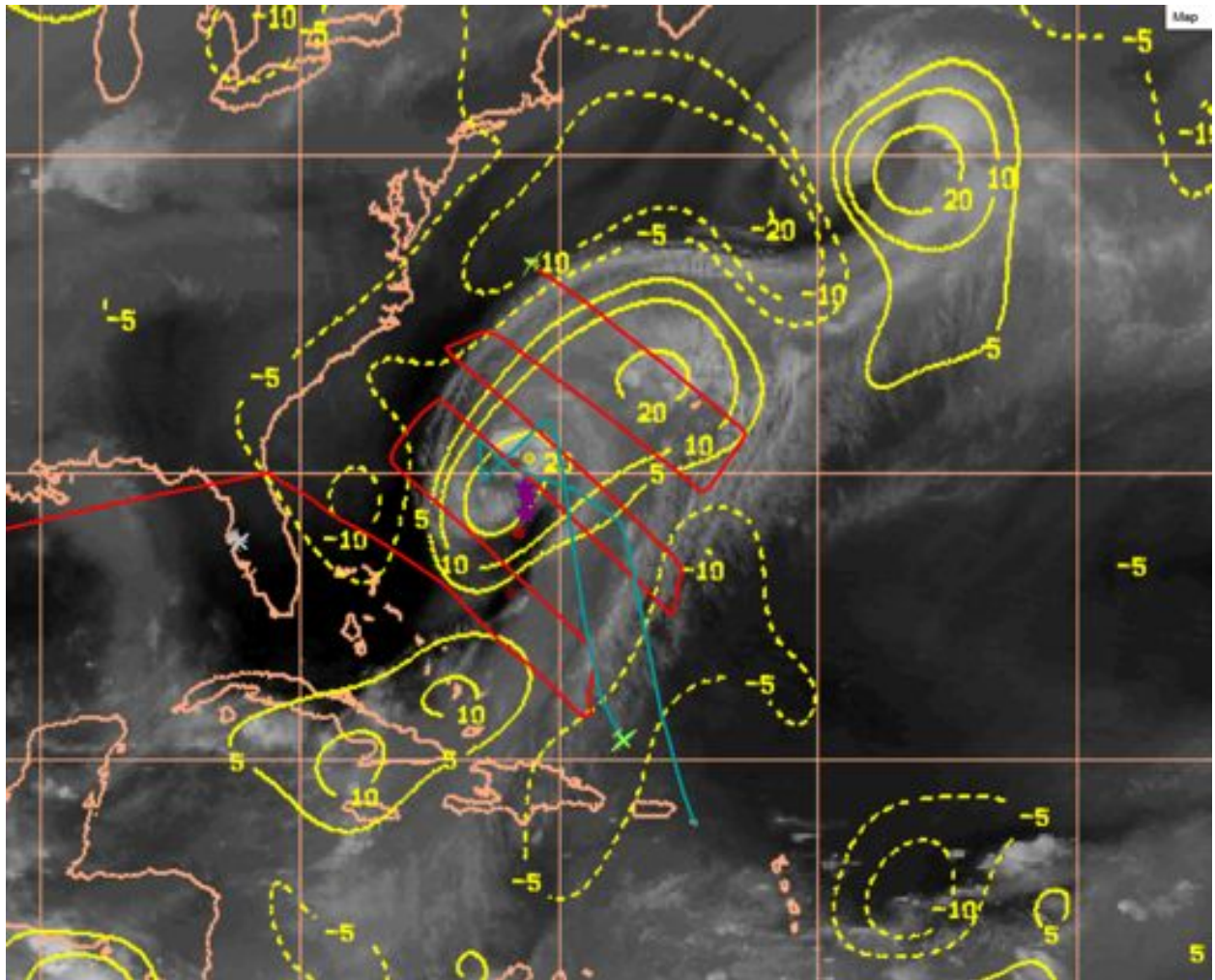


This is the 0551 Z sonde that was sampled near the edge of the outflow jet. There are some 30 – 35 knot winds at ~ 175 hPa that may be part of that jet, perhaps part of the mid-latitude flow interacting with the storm.

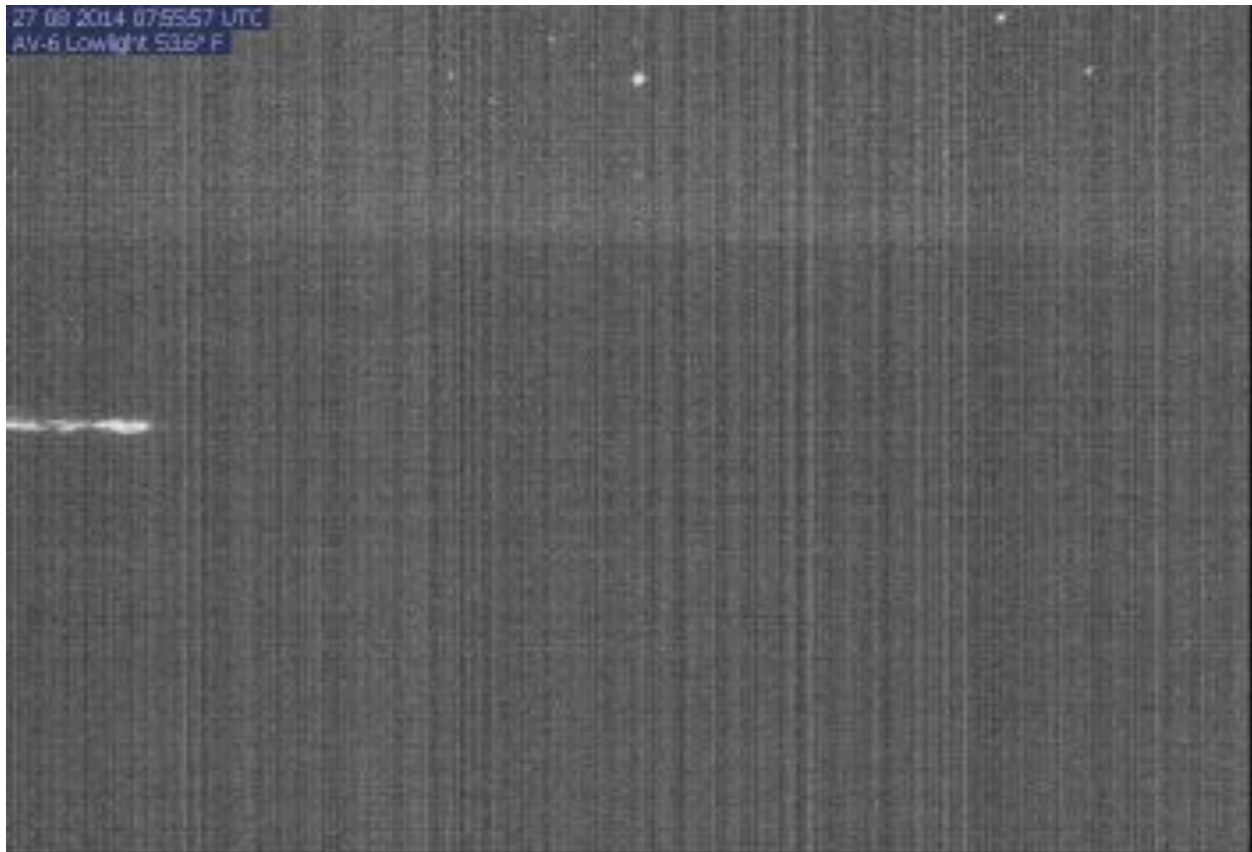




Water vapor imagery looks very extratropical. Downstream wave amplified substantially compared to the beginning of the flight. Significant change in upper-level flow in the cloud region east of center that extends from SW to NE. Looks like an elongated upper anticyclone over this region.



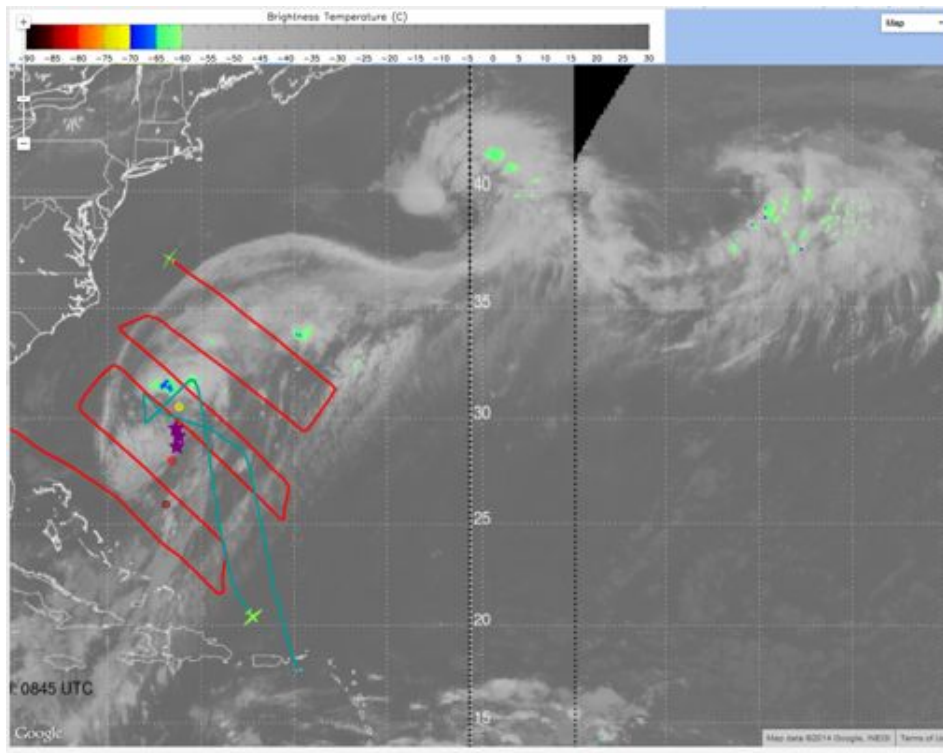
06Z Upper-level divergence pattern. Flight pattern covers most of the divergence region, but only gets a little ways into the convergence regions.



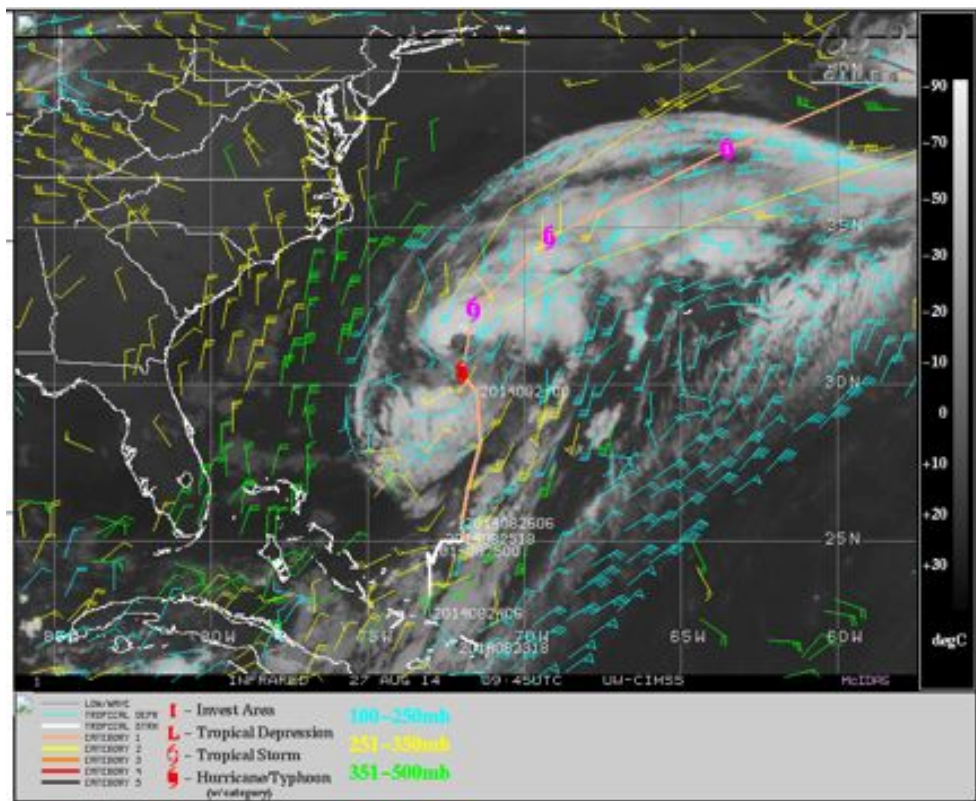
0756Z Bermuda showing up in the low-light camera to the left of the aircraft. Stars showing up as well.

0922 AVAPS reporting a system fault as we approach the last drop point. This drop was to get measurements in the clear air beyond the cloud shield, but we are now (0927Z) out of the NOTAM area and can't do the drop.





Another view of Cristobal and the downstream development of two waves.

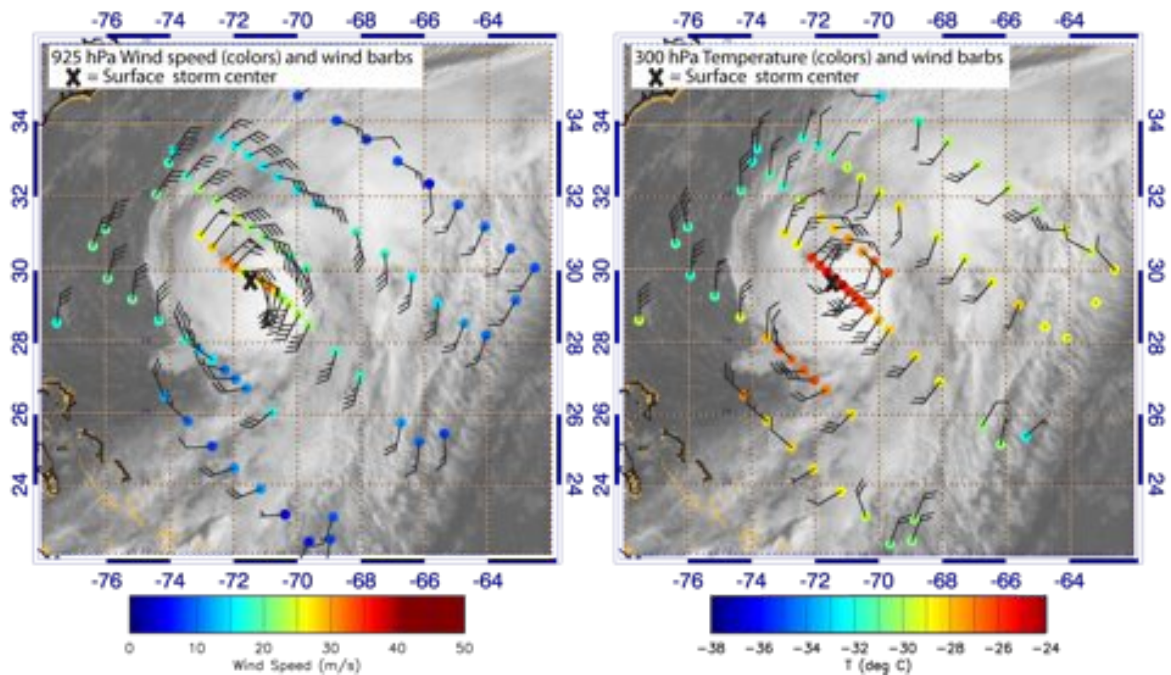


GOES IR and upper winds at 0945Z.



1105 Starting descent

1143 AV-6 has landed



The above figures show the sonde distribution in a storm-relative reference frame. Wind barbs show storm-relative winds. (Left) Total (ground-relative) wind speed at 925 hPa and (right) 300 hPa temperature. The system was tilted toward the northeast with height.

### Instrument summaries

#### AVAPS, Transit/Flight 1

84 dropsondes were loaded comprised of 75 normal science sondes and 9 engineering test sondes. Of these, 83 were deployed while one returned in the launcher due to a jam on the final launch attempt. Two sondes returned no data due to problems described below while transmission from a third sonde was lost at 300 mb. Two additional sondes were not processed in real time but the data are fine and will be made available. Data returned all appeared to be of high quality and the telemetry return was better than or equal to last year. Only two soundings exhibited notable gaps in their data. One fast fall was observed. The system performed extremely well in a sequence of rapid drops and all 8 channels were active for an extended period. A near-sustained deployment rate of 2.5 minutes was supported and a more rapid deployment rate is possible for up to 8 sondes.

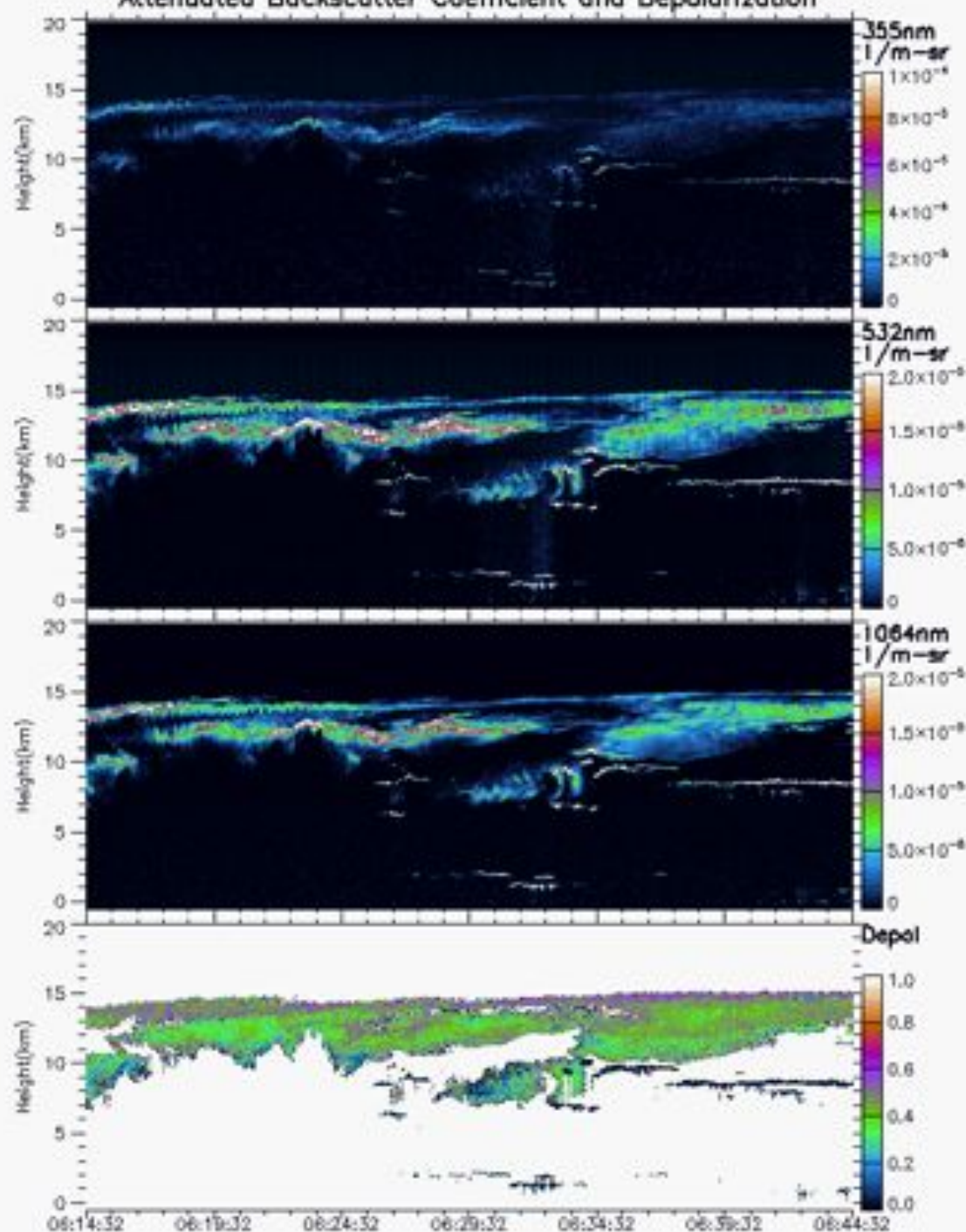
There were three issues encountered during the flight, all associated with the engineering test sondes. The first was a failed update of a configuration file designed to accommodate the longer-than-normal descent time of one of the engineering sondes. Because of the problem all data was lost from a single sounding and a couple planned drop locations were skipped while recovering from the problem. The

second issue was a launcher jam of an engineering sonde on the 48<sup>th</sup> deployment. The sonde was not ejected during the normal launch attempt and initial attempts to reset the shuttle failed. The sonde was freed during further attempts to reset the system but resulted in an unplanned deployment of the sonde. Good quality data was obtained from this sounding. It would have been possible to return to normal drops sooner than actually occurred, but an additional delay was associated with a crew shift. Finally another engineering sonde became jammed in the launcher during the final deployment attempt. This sonde could not be freed before the aircraft exited the region of allowable drops and the aircraft landed with the sonde in the launcher. Post flight inspection confirmed the jam was associated with differences in the engineering test sonde. No additional engineering sondes will be used and no additional problems of this nature are expected during the remainder of the campaign.

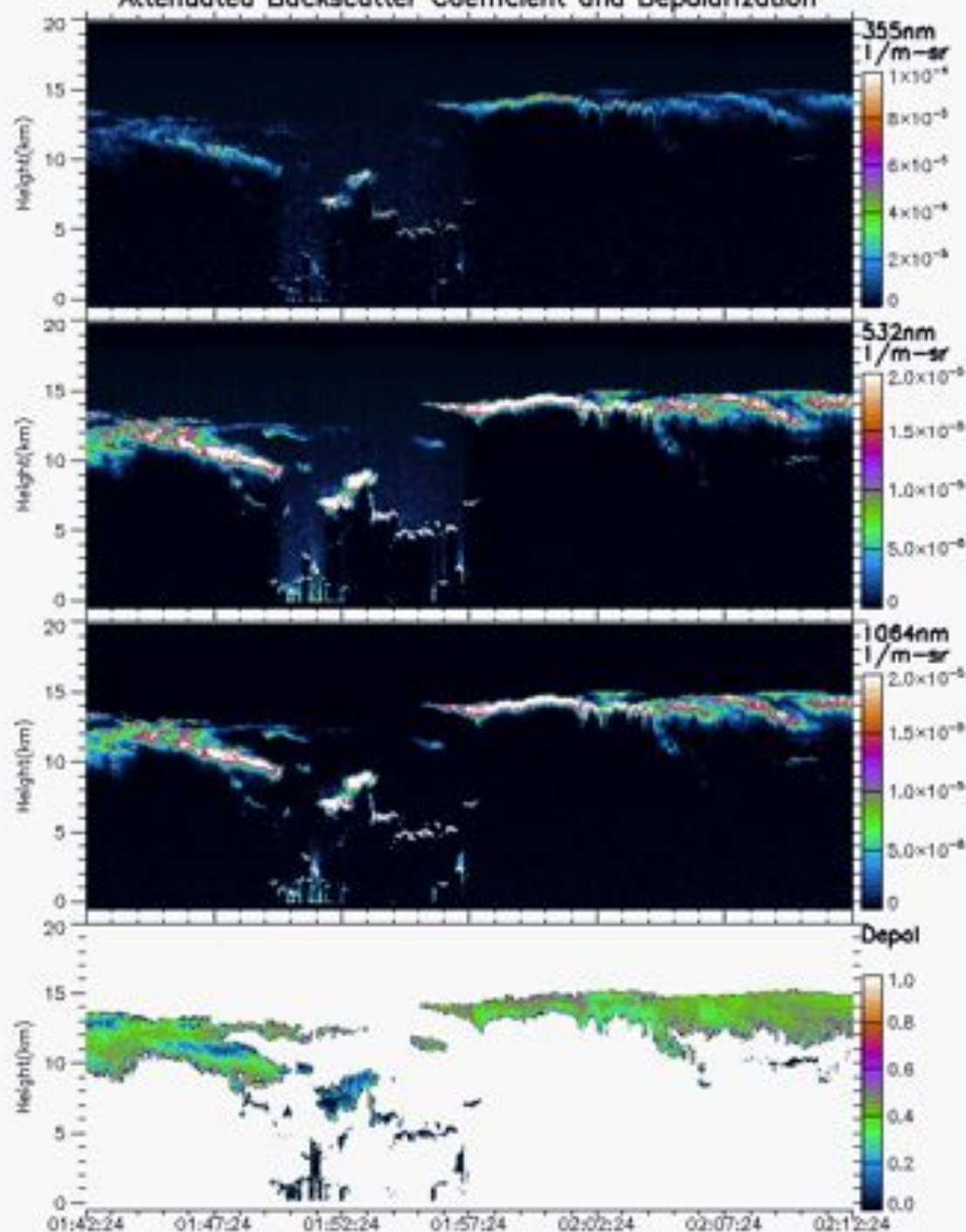
#### CPL

CPL worked well for the 26-27Aug14 flight. No data issues were discovered and the instrument temperatures remained inside thresholds. CPL started data flow at 14:12:22 UTC on 26Aug. and ended data flow at 09:37:44 UTC on 27Aug. Many complex cloud systems were overflown, with an example attached (30-minute swath in Segment D where there appears to be waves in the cirrus at 06:21 at 13.5 km). Approximate time of closest approach of the hurricane center was near 02:06 in Segment C (image attached).

UAV-CPL HS3\_14 27Aug14-0  
Attenuated Backscatter Coefficient and Depolarization



UAV-CPL HS3\_14 26-27Aug14-C  
Attenuated Backscatter Coefficient and Depolarization





## S-HIS

J. Taylor, Dan DeSlover, Claire Pettersen; SSEC, University of Wisconsin-Madison

### Summary:

S-HIS MTS products were available throughout the flight, except for those periods in which Ku was intermittent. Complete S-HIS data will be available in post-processed products.

S-HIS detector temperature increased slowly beginning at approximately 0000 UTC, but remained below 80 K (nominal temperature is 77 K). This small change in temperature should have negligible impact on data quality. A power cycle was not required.

To ensure mitigation of this issue, an at-altitude power cycle of the S-HIS at 45 minutes prior to the first science waypoint will be requested for the next flight. The power off cycle will be 15 minutes duration.

There were a significant number of high clouds and overshooting tops in the system, resulting in some interesting observations. SNPP and AQUA overpassed the system at roughly 0618 and 0646 UTC (Aug 27). The overpasses were roughly 235 nautical miles southeast and 285 nautical miles northwest of AV-6 (measured along the AV-6 flight track), respectively. The tracks are shown in Figure 3, and a Google Earth image of the S-HIS data from near the SNPP overpass time overlaid on the CrIS data is included in Figure 4.  $895 - 900 \text{ cm}^{-1}$  brightness temperatures are shown for both instruments.

### Timeline (All times are UTC and are only approximate):

- 20140826T1228 GH engine start
- 20140826T1247 Ku ON and transmitting
- 20140826T1302 SHIS Power on
- 20140826T1309 Takeoff
- 20140827T0035 S-HIS detector temperature and cooler behavior change noted
- 20140827T0915 S-HIS detector temperature at roughly 79K (2K above nominal, slow ramp since 0035)
- 20140827T0934 S-HIS descent heaters on
- 20140827T0954 Instrument power OFF before descent (IL42, IL41, DC42, DC41)
- 20140827T1011 Instrument power ON (DC41, DC42, IL41, IL42)
- 20140827T1142 Instrument power OFF (DC41, DC42, IL41, IL42)
- 20140827T1143 Landing

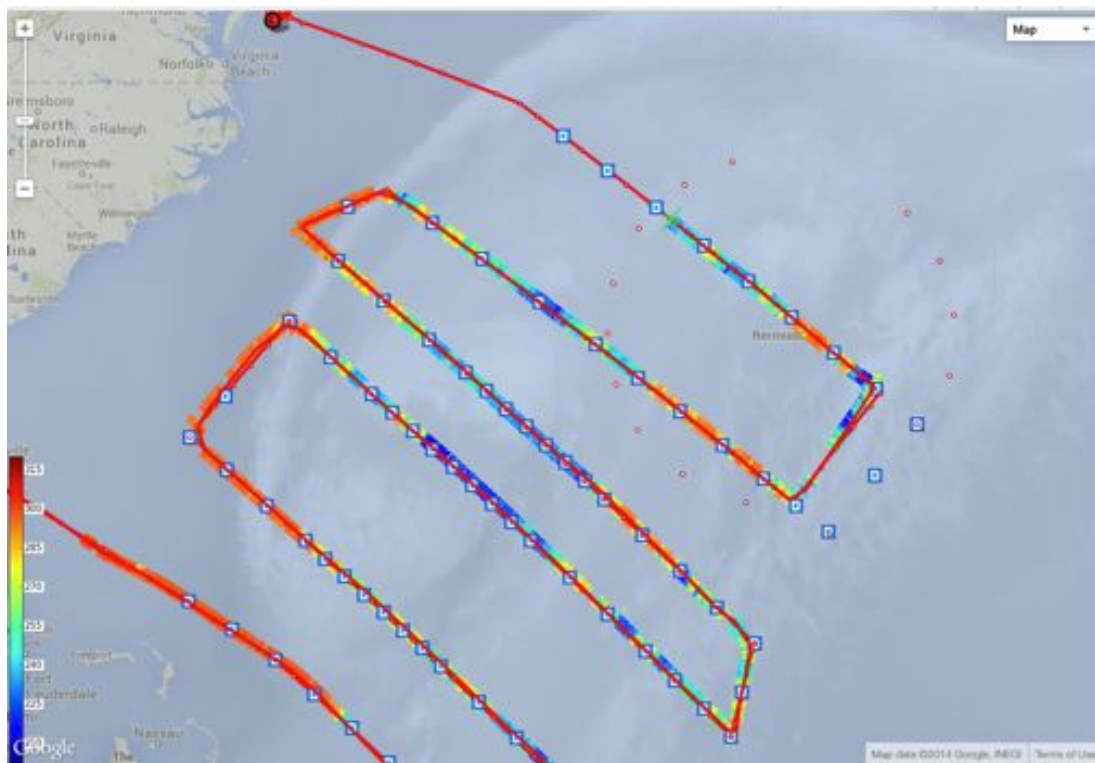


Figure 1: S-HIS 895-900  $\text{cm}^{-1}$  Brightness Temperature image overlaid on GOES IR in MTS.

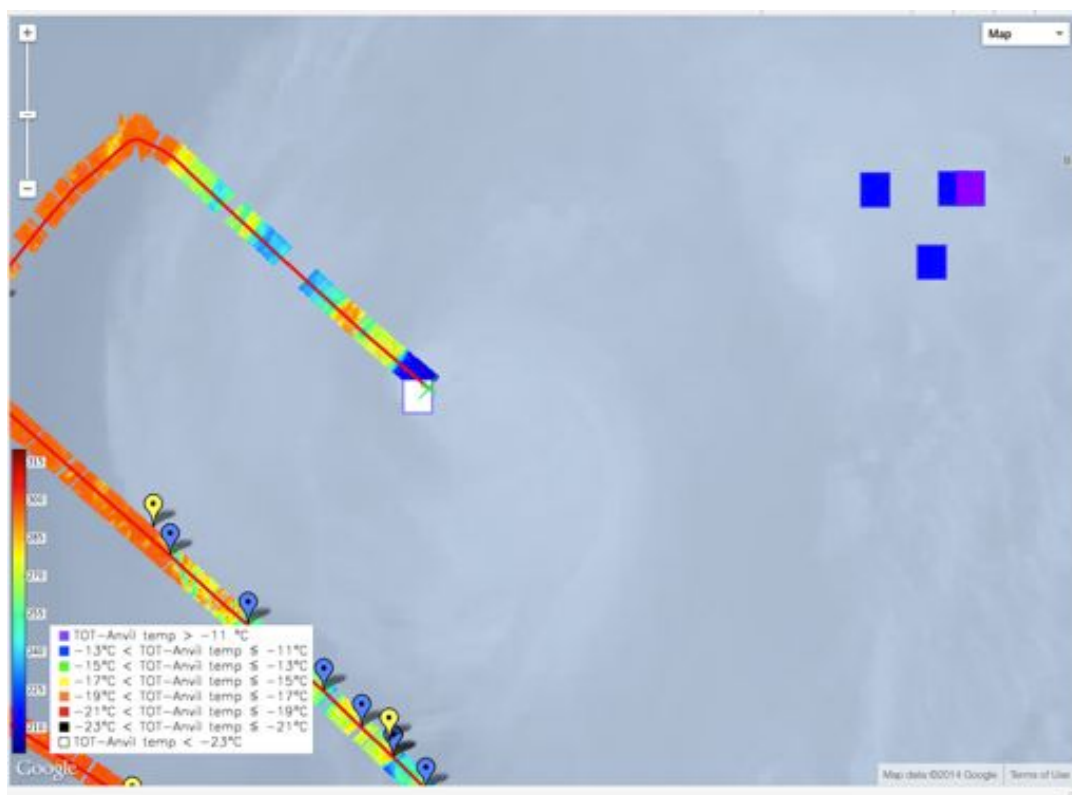


Figure 2: S-HIS 895-900  $\text{cm}^{-1}$  Brightness Temperature image overlaid on GOES IR. Overshooting tops indicated.

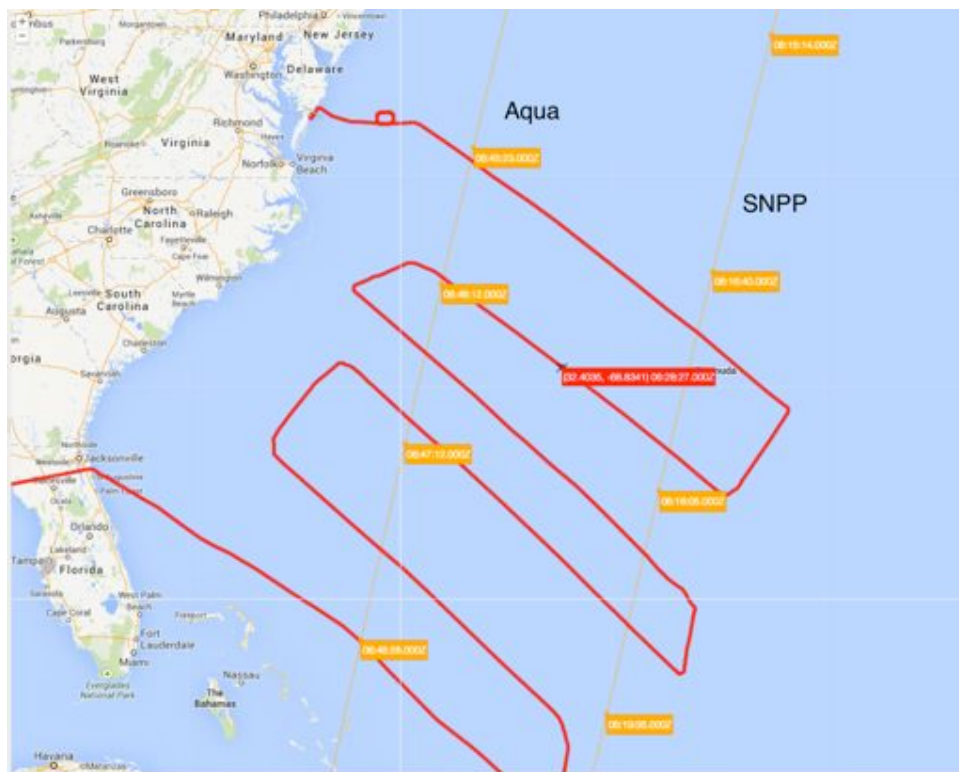


Figure 3: Suomi NPP and Aqua overpasses are indicated.

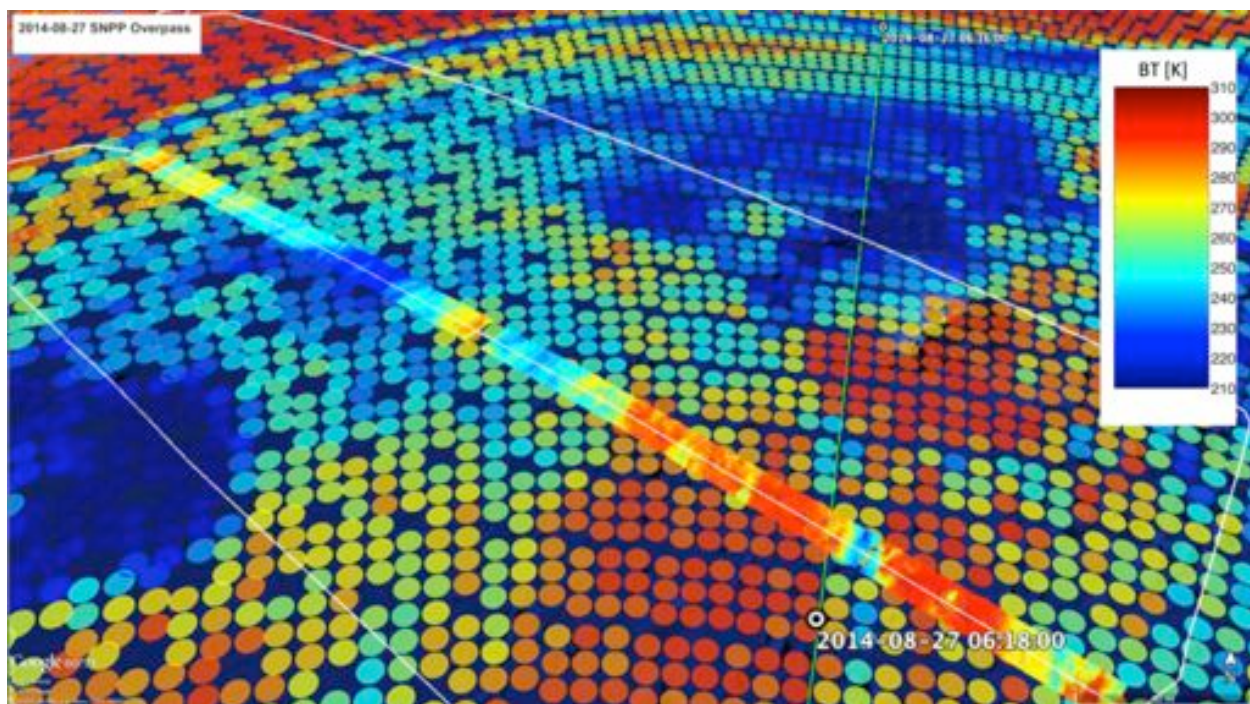


Figure 4: Google Earth image showing S-HIS data overlaid on CrIS data near time of SNPP overpass of Hurricane Cristobal. 895 – 900  $\text{cm}^{-1}$  brightness temperatures are shown for both instruments.